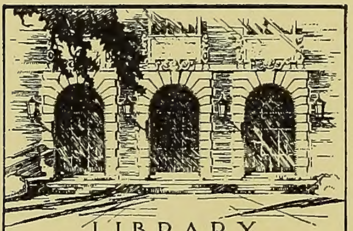

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UNIVERSITY OF ILLINOIS

UNIVERSITY RESEARCH BOARD

ELECTRONIC DIGITAL COMPUTER

This volume is bound without issues
for May 15/ June 15, 1952
ch ~~is~~/are unavailable.

January 15, 1952 - March 15, 1952

2b

UNIVERSITY OF ILLINOIS

UNIVERSITY RESEARCH BOARD

ELECTRONIC DIGITAL COMPUTER

TECHNICAL PROGRESS REPORT

January 15, 1952 - March 15, 1952

26

I. USE OF THE ORDVAC DURING THE CLOSING PERIOD AT THE UNIVERSITY

A table is presented in this section which shows the distribution of time for the ORDVAC during the interval from January 15th through February 9th, 1952. During the week of February 4th to 9th, the ORDVAC was not used on useful codes to any large extent, but instead, the period was used to eliminate two marginal errors which had occurred from time to time:

(1) A switching transient in the operate - control switch produced errors occasionally and was fixed,

(2) A gate tolerance affecting the red and black gates of the R_I R_{II} registers had eventually caused leapfrog routine failures and was repaired.

The leapfrog routine was operated for a period of ten hours on February 7th without terminating in a failure, after the repairs mentioned above were made. The leapfrog was again operated three hours and fifty-nine minutes on February 9th which terminated in a failure. On the basis of these tests the machine was believed to be in a reasonably error-free state and ready for dismantling and shipment.

TABLE I

DISPOSITION OF ORDVAC TIME 1/17/52 THROUGH 2/9/52

ROUTINES FOR TESTING MACHINE:

A.	Stripes	3:55
B.	RAR	4:02
C.	Leapfrog	29:15
D.	Leapfrog abstract (crippled leapfrog)	:34
	TOTAL:	37:46

TIME FOR E.D.C. GROUP CODES AND PROBLEMS:

A.	Clutterham	25:56
B.	Wheeler	15:20
C.	Gregory	2:30
D.	Tross	2:25
E.	Miscellaneous	2:23
	TOTAL:	48:34

TIME FOR NON-E.D.C. CODES AND PROBLEMS:

A.	Control Systems Laboratory	65:00
B.	Civil Engineering Research	9:26
C.	Ballistic Research Laboratories	5:41
D.	Electrical Engineering Research (Welkowitz)	5:33
E.	Physics (Kalos)	2:55
	TOTAL:	88:35

ENGINEERING MAINTENANCE AND TROUBLESHOOTING:

The time listed under routines for testing the machine is not included here.

TOTAL:	154:43

TIME ON:

Approximately	354:

II MOVING OF ORDVAC

On February 11th the group started to dismantle the machine and during the course of this week preparations were made for shipping it. The machine was shipped with its covers removed and with all the vacuum tubes except the memory tubes in place. It was mounted in a moving van on February 15th and left Champaign on February 16th. It arrived at Aberdeen on February 19th and the ensuing week was spent in assembling the machine. By February 25th the machine was assembled and ready to be tested, but the installation of

the air-cooling unit to be provided by the Ballistic Research Laboratories was not finished. During the next few days some effort was put on the Williams test rack and it was placed in operation. It was found that pulse voltages existed on the power lines at the Ballistic Research Laboratories which caused errors in this Williams test rack. Appropriate steps were taken to correct this in both the test rack and the ORDVAC itself. The installation of the air-cooling equipment was finished on February 29th and the testing of the ORDVAC started on that day. By March 2nd the ORDVAC had been generally tested enough so that the leapfrog routine ran for 2 - thirty-five minute intervals, each of which ended in an error. It is perhaps desirable to record the errors in assembly or transit which needed to be repaired in order to put the machine into operation. These are:

1. The a.c. power to operate the d.c. turn-on relays was connected to 6.3 volts instead of 110 volts,
2. Two wires were interchanged during the assembly of the d.c. turn-on circuit in another portion of the machine,
3. A 10 - 32 nut shorted to ground a cathode circuit in a clear driver-driver, requiring the replacement of six resistors,
4. A filament lead in the address generator was broken,
5. The aluminum supports for a small panel of condensers in the address generator were broken,
6. A piece of solder shorted one of the address generator terminals to ground requiring the replacement of two resistors,
7. Two deflection resistors used to connect the slave tube to the main memory were shorted together,
8. Three memory chassis had faults which prohibited storage and hence needed to be replaced,
9. A wire in memory position 2^{-19} was broken and shorted to ground which required the replacement of a 470 K resistor as well as the wire,

10. A grid-cathode short in tube 29 of Chassis C, required the replacement of the tube,

11. Several order gate wires had been shorted together during shipment and needed to be untangled,

12. A cathode of tube 16 in the register selection chassis was shorted to ground by loose solder,

13. The gate tolerance "bumping" voltage in the negative direction of the gate driver R_{II} chassis was changed from -15 to -23 volts because one of the gates did not go sufficiently negative to provide a reply to Chassis A. It is difficult to know whether this was a part of the shipment problem or was unrelated to it,

14. An error occurred in the gating of the R order which eventually required the replacement of a tube.

The correction of these errors made it possible to treat the computer as an operating instrument and to use routines as a means for diagnosing other intermittent failures which occurred. All of the additional failures noted were due to tubes. Eighteen small tubes were replaced as a result of hammer-testing chassis at the same time that the "crippled-leapfrog" routine was in operation. Forty-two 5687 tubes in the clear drivers for the registers were replaced because a number were operating at zero bias, and although this did not necessarily interfere with the operation it appeared desirable to change them while the University personnel were present. Similarly, and for the same reason, twelve 5687's in the shift counter were replaced. The total number of small tubes replaced was seventy-two. Seven memory tubes were replaced for reasons which may or may not have been associated with shipment.

The machine successfully performed the required read-around and flaw tests on March 5th. On March 5th and 6th the machine successfully carried out twenty hours of operation with one failure on the final test routine. The group remained at Aberdeen for several additional days to check further the

memory and to obtain a satisfactory run of the leapfrog routine. On March 8th the leapfrog routine was operated for five and one-quarter hours which terminated in a failure due to a filament failure of a tube in the digit resolver. The machine was put under the cognizance of the Ballistic Research Laboratories effective 8:00 AM March 10, 1952.

The following individuals worked at Aberdeen between the dates listed:

Edwin L. Hughes	February 19th through March 8th
Walter E. Jones	February 20th through February 28th
Thomas E. Kerkering	February 19th through February 24th
Harold E. Lopeman	February 19th through February 24th
Ralph E. Meagher	February 19th through March 1st
John P. Nash	February 28th through March 9th
James E. Robertson	February 27th through March 9th
Theodore Shapin, Jr.	February 19th through March 8th

III ORDVAC MANUAL

One systematic editing job of the manual has been carried out. Three copies of it exist. It has been decided to add a chapter containing the codes and descriptions of the leapfrog routine, the final test routine, the read-around routine, the crippled leapfrog routine, the flaw test, and the dynamic adder-digit resolver test routine. It will also be necessary to go through the manual an additional time to make some corrections. One copy of the manual will then be sent to Ballistic Research Laboratories to complete the requirements of the original Ordnance contract, and steps will be taken to have about three-hundred copies multilithed. It is believed that this will take about four weeks.

At the request of the Ballistic Research Laboratories and chargeable to the moving contract, a set of "Van Dykes" of all of the ORDVAC drawings is being prepared by the Photographic Office for Ballistic Research Laboratories.

The group at the Ballistic Research Laboratories now has three complete sets of drawings on ORDVAC circuits.

IV CODES TO BE SENT TO ORDVAC

A number of codes will be taken to Aberdeen to be tried on the ORDVAC in the very near future. There is known to be ready at the present time the following:

1. One code - CSL - M. Davis
2. Random Walk Problem - Wheeler-Wall, to be taken by David Clutterham
3. Cosmic Ray Shower Moments - Kalos, to be taken by Davis
4. Refraction of Shock Waves - Clutterham
5. Ball on a beam - Carlson
6. Simultaneous Linear Equations - Mrs. Benesch to be taken by Carlson

V CODING AND PROGRAMMING

Work has continued on the refraction code in an effort to eliminate its errors. Two errors were found: (1) Certain missing roots were accounted for by observing that a negative case had not been considered and (2) an error in the sign of one of the quantities calculated could apparently account for at least some of the bad pressure ratios found when the problem was previously run. These errors were corrected and a new tape will be tried at Aberdeen.

A complete report on the eigenvalue problem as coded for the ORDVAC has been written. However, certain modifications in it were made because of a lack of a high-speed input at Aberdeen.

A new leapfrog routine using the code for the University of Illinois machine has been written in such a way that it will operate in a memory having either 512 locations or 1024 locations. This routine is more complete than the old leapfrog routine and gives more information about the state of the machine.

A new decimal order input routine for the University machine has been written and checked. A complete description of this program is now being written up. A rough draft of a routine for solving simultaneous algebraic equations has been written.

Some work is also being done in the writing of subroutines for the expansion of functions by means of a series of Tshebysheff Polynominals. The rapid convergence in simple form of such series makes them desirable for use in subroutines.

VI PROGRAM OF WORK FOR THE CODING AND PROGRAMMING GROUP

A. Test Routines

  1. Leapfrog (written but not tested)
  2. Memory tests (revisions are desirable)
     - a. Read-around
     - b. Flaws
  3. Adder Digit-Resolver test (should be discussed)
  4. Crippled leapfrog (should be discussed)

B. Programs

  1. Subroutines
     - a. Input and Output
       - (a) Decimal order input
       - (b) Conversion routines
     - b. Floating Point Routines (investigate differences between binary and decimal routines)
     - c. Double Precision Arithmetic
     - d. Evaluation of functions
       - (a) Square root (requires translation to Illinois code from ORDVAC code)
       - (b) Sine, cosine, exponential
       - (c) Arctan, etc.
       - (d) Logarithm

       } Require writing and finding coefficients

2. Processes
   - a. Solution of simultaneous algebraic equations (half written)
   - b. Inversion of matrices (not done)
   - c. Determination of eigenvalues and eigenvectors (translation and minor changes)
   - d. Solution of ordinary differential equations (translation)
   - e. Integration (investigate)
   - f. Interpolation (defer)
   - g. Finding roots of algebraic equations (investigate)

     (a) Real
     (b) Complex

   - h. Sorting (defer)
   - i. Solution of partial differential equations (investigate)

C. Checking Routines

1. Code checker (investigate)
2. Post Mortem (translation)
3. Address finder (translation)
4. External blocking routine, tape controlled (investigate)

D. Diagnostic Routines

1. This important category of routines has been only very superficially considered. More work will be done.

VII MEMORY

Memory work is now being carried out for the University of Illinois Computer. This memory is now commonly being designated as Williams V. Preparations are being made to alter Williams II so that it may be used to check the read-around of every address of the memory for tube testing purposes and preparations are also being made to use the old Williams III unit as an additional test bench for memory tubes and circuits.

The circuit to be used for the individual chassis of Williams V is given in drawing 384. It differs in a number of details from the circuit

used in the ORDVAC memory. However, some considerable caution has been exercised to see that the new circuit differs only in ways which are improvements upon the ORDVAC memory and only in such a way that the changes are well understood or are very easily alterable to the exact circuit of the ORDVAC memory. The Williams V circuit has a somewhat different system for the detection of a dash. In ORDVAC a dash is sensed by the presence of a dash and a dot is sensed by the absence of a dash. In Williams V for the Illinois computer a dash is sensed by the absence of a dot and a dot is sensed by the presence of a dot. Logically the systems are the same but the newer system allows a greater time tolerance in the dash test pulse and, in fact, allows it to be longer which should reduce the flaw problem somewhat.

At the present time there are 11 chassis complete and tested. Ten of these are numbered ones, the other is a model, although it may be used in all of the circuits as it is identical circuitwise and exterior connectionwise. It has been the practice to check each chassis with the same set of tubes in order to isolate tube troubles from wiring errors and unsoldered connections.

One hundred cathode ray tubes have been received of the 3KP1 type. Of these, twenty-four have been sent on along to the Ballistic Research Laboratories, and preparations are being made to test the others soon. A special cathode ray tube which is supposed to have a particularly high read-around ratio and a small number of flaws is being sent for test from RCA.

The IBM Company has reported a mud-hole effect which states that if a particular spot which is a dot is consulted a number of times in succession, and then there is a pause of perhaps ten or twenty milliseconds, this spot will

change to a dash. This has been looked for on one cathode ray tube and has not been found.

VIII INPUT-OUTPUT WORK

A number of units are now available for use as input-output equipment on the University of Illinois computer. Some of these require alterations before they can be used with the computer. This work is being carried out now. The present goal is to increase the speed of input and output for the University of Illinois computer over that available in the ORDVAC. It is most convenient to summarize all of the units which we now have on hand or on order in a table which is presented as Table II.

TABLE II

NAME	QUANTITY	FUNCTIONS	COMMENTS
Page printer with tape punch keyboard	2 on hand	Punch a tape from keyboard. Print from Teletype start-stop signals.	These units have been converted to the code used on ORDVAC.
Transmitter-Distributors	2 on hand	Generates stop-start code from a punched tape.	Standard Units 6.1 sexadecimal characters per second.
Non-typing reperforator	1 new unit 1 used unit	Perforate a tape from start-stop signals	Standard Units 6.1 sexadecimal characters per second.

The above three units were used to prepare and duplicate tapes for ORDVAC.

NAME	QUANTITY	FUNCTION	COMMENTS
Fast transmitter distributor	1 on hand	Computer input reader	Reads 26 sexadecimal characters per second. Available for new computer now.
Ferranti reader ($1,875.00)	One for delivery 5/30/52	Computer Input reader	Will read 200 sexadecimal characters per second.
Western Union reperforator ($250.00)	2 on hand	Magnet operated tape punch	Needs new die block for on-center sprocket hole. 15. per second. Could be used as output for U. of I. computer. Also suitable for tape preparation.
Western Union Transmitter ($150.00)	1 on hand 1 on order	Magnet operated tape reader	Reads 15 sexadecimal characters per second. Suitable for tape preparation.
ARPE reperforator (Teletype special)	1 on hand	5 magnet motor driven tape punch	Initial output for Illinois machine. 25 per second. Needs a drive (motor and clutch).
Transmitter-Distributors	1 1/2 on hand	One unit is modified for a tape comparer, the other furnishes spare parts.	6.1 sexadecimal characters per second.
X-6 Transmitter	1 on hand	Used with above for tape comparer.	6.1 sexadecimal characters per second.

IX PROGRAM FOR THE EXPERIMENTAL GROUP

A. Construction of University of Illinois Computer which requires the following:

1. Williams V memory, construction and test,
2. Some changes in orders affecting the end connections,
3. Memory control chassis,
4. Construction of covers,
5. Further work on Ferranti input to have a 200 sexadecimal character per second input and further work on high speed punch to provide 25 sexadecimal characters per second output, and their circuits.

B. Input-Output

1. Work on magnetic drum to determine circuits, present drum characteristics (Task 24),
2. Study of logical arrangement for interrelation of drum and computer.

C. Memory

1. Further investigation of present memory with new circuits to improve read-around and reduce flaws, especially if manufacturers do not improve commerical tubes,
2. Study of other detection systems and tubes.

D. Transistor Circuits

1. Study of presently available transistors and their computer circuits. Analysis by means of computer,
2. Study of possible new transistor circuits and their effect upon logical arrangement. These could be carried out with ONR support.

E. Logic

1. Study of computer logic,
2. Use of computer to minimize logic in new designs.

X ORDERS FOR THE UNIVERSITY OF ILLINOIS MACHINE

It has been proposed that certain alterations be made in the list of orders available on the University of Illinois machine as compared with the list available on ORDVAC. Each of these will require some alterations of the ORDVAC circuits. It is convenient and possible to make these changes on the University of Illinois machine at its present stage without noticeably

delaying its completion. A list of the code and orders for the new machine will be available shortly. The changes from the ORDVAC to the University machine may be briefly noted as follows:

1. The left shift order will still be "arithmetically correct" and in particular will permit a shift from 2^{-1} to 2^{0} in R_1 and a shift from 2^{-1} R_2 to 2^{-39} R_1.

2. The divide order will be changed because of the change in the left shift order listed in (1). The divide order will shift the contents of R_2 into R_1 (except for 2^{0} R_2)

3. Because of the change in the left shift order in (1) the print order will be revised so that upon printing the contents of R_2 it will also be shifted to R_1 (except for 2^0 R_1).

4. The transfer part of the A order will be eliminated.

5. The control transfer orders both unconditional and conditional will be changed so that the sexadecimal code used to designate them will be more uniform and will be easily indicated by inspection of the kind of transfer involved.

6. The sexadecimal designation for the conditional stop orders will be changed and will differ from the corresponding transfer orders one digit in each case. Thus there will be 4 conditional stop orders.

XI CONSTRUCTION WORK

The following construction work has been carried out during the past two months.

1. Fifty (50) memory chassis have been built, 10 of which have been wired,
2. ORDVAC dismantled, shipped and assembled,

3. +680 volt power supply used on ORDVAC rewired,
4. Frame for memory, one-half finished.

R. E. Meagher.

R. E Meagher

March 24, 1952

REM/nrh

ELECTRONIC DIGITAL COMPUTER

TO: Executive Committee, Computer Subcommittee, University Research Board

FROM: R. E. Meagher

DATE: April 22, 1952

A proposal has been sent to ONR requesting the extension of the Task 24 contract for two years from July 1, 1952 at a cost of about $31,000.00 per year. The work to be covered by the proposal would include Magnetic Drum work, High Speed Memory work, or Transistor Circuit work. Similarly, a proposal has been sent to ONR requesting the extension of the Task 30 contract for two years at the rate of $10,000.00 per year.

One copy of the manual has been sent to the Ballistic Research Laboratories. This completes the requirement under the original Ordnance 11362 contract.

Mr. David Muller, now of the California Institute of Technology, has been awarded a Post Doctoral University Fellowship and will be in the University after September 1, 1952. He is interested in studying various aspects of computer logic, as well as studying mathematics.

Mr. Frazier and Mr. Sands of the architect's office have prepared a proposal for a cooling system for the University of Illinois computer which appears attractive. The system proposes a refrigerating system capable of removing 54,000 BTU's per hour, and a radiator using water as a coolant to remove the rest of the heat required from the computer. The cooling system would be mounted in the basement nearly below the computer.

An estimate has been made that the entire system including installation and costs to the architect's office would amount to $3,000.00. Bids for this work are being obtained at the present time. In any case, it seems desirable to rotate the computer so that it is at an angle of approximately 40 degrees with respect to its present position, and so that the cooling air for the machine can be admitted through the floor of the room. This removes one duct from the computer.

An investigation is currently being made to ascertain the feasibility of a teletype connection between our group and the ORDVAC. According to present estimates this would cost about $60.00 a month plus $1.00 for each five minutes the circuit is used. A reperforator which is not normally furnished by the Bell system would have to be attached at each end of the line. Permission will have to be obtained to install these reperforators on Bell telephone lines. It will also be necessary to secure the permission for this installation from the Ballistic Research Laboratories, but preliminary contacts with Dr. Leutert indicate that he is in favor of it, but that he does not know what Army restrictions, if any, might apply.

The seminars during the past month have been:

March 19, 1952
Williams V by Joseph M. Wier

April 2, 1952
Numerical Problems in Psychology by Dr. Charles F. Wrigley

April 9, 1952
Computer Input-output Circuits by Theodore Shapin, Jr.

April 16, 1952
Stability and Convergence Problems in Numerical Solutions of Simple Dynamical Systems by Professor N. M. Newmark

April 23, 1952
Machine Solution of the Dynamic Effect of Rolling Loads on Highway Bridges by Mr. A. J. Carlson

The list of personnel associated with the group remains unchanged from last month's list.

A financial summary prepared by Mr. Michael is attached.

R. E. Meagher

R. E. Meagher

REM/nrh

Enc.1

FINANCIAL REPORT
as of
April 15, 1952

	U.S. ORD. 11362	U.S. N6ORI Task 07124	U. S. N6ONR Task 07130	IND. COST COMP. MEAGHER	GRAD. RES. COMP. MEAGHER	IND. COST MATH TAUB	ELEC. DIG. COMP.	U.S. ORD. 680	TOTAL
EQUIPMENT	14,496.00			10,088.21	1,074.49	32.21	35,004.11		60,695.02
MATERIALS	70,308.56	5,117.61		32,026.31	18,449.18		14,406.74	107.59	140,415.99
SALARIES	108,805.18	8,265.45	6,320.82	33,724.63	32.40	7,333.34	6,251.87	4,947.69	175,681.38
OVERHEAD	44,208.72	3,361.65	2,499.23					1,957.50	52,027.10
WORK. COMP.	1,622.78	107.19	108.55					40.08	1,878.60
RETIREMENT	4,671.11			1,775.79		305.84		204.50	6,957.24
TRAVEL	3,535.25	362.09	297.19	1,742.49	443.98	121.58	861.13	1,830.36	9,194.07
TELE-TELEG.	2,352.40			602.05			164.24	117.80	3,236.49
BUILDING AND MOVING				1,794.25			18,311.91	1,322.53	21,428.69
TOTAL:	250,000.00	17,213.99	9,225.79	81,753.73	20,000.00	7,792.97	75,000.00	10,528.05	471,514.53

Prepared by:

G. W. Michael,
Admin. Assistant

UNIVERSITY OF ILLINOIS

UNIVERSITY RESEARCH BOARD

ELECTRONIC DIGITAL COMPUTER

TECHNICAL PROGRESS REPORT

March 15, 1952 - April 15, 1952

I CODES PUT ON THE ORDVAC

Shock Wave Problem. After its failure at Aberdeen on March 16 Clutterham and Taub found faults which could account for all erroneous results. It was run again April 10 and failed, apparently because of a tape punching error. This has been corrected and the code has been sent back to Aberdeen.

Eigenvalues and Eigenvectors. Robert Gregory of the Computer group and Jack Neuhaus of the Psychology Department went to Aberdeen to run some matrix problems on the ORDVAC. During the period 5 PM April 14 to 7 AM April 15 they obtained eigenvalues and eigenvectors for 23 matrices, 15 of them being of order 20 or 23 and the remainder of order 7 or 8.

Simultaneous Equations. This code solves a set of simultaneous linear algebraic equations by using a direct method and back substitution. With the ORDVAC memory, 40 equations can be handled. The time required will be about 3 minutes. This program has been tried once, a coding error has been found and corrected, and it has been returned to Aberdeen for another test.

Ball On A Beam. A. J. Carlson of the Civil Engineering Department successfully carried out the problem of a ball rolling on an idealized beam and additional sets of data with other constants for the same problem are now at Aberdeen waiting to be worked.

Cosmic Ray Shower Moments. M. H. Kalos of the Physics Department has a code at Aberdeen for the calculation of cosmic ray shower moments. This was tried once on the ORDVAC before it was moved and the first five

moments were successfully calculated. After the ORDVAC was moved to Aberdeen, Mr. Davis of the Control Systems Laboratory put the problem on the machine and calculated a sixth moment, but there is a question whether the calculation was correct because of printing errors. The code is waiting to be put on the machine again.

Random Walk Problem. The original tape has been run successfully at Aberdeen (it ran before the machine was moved) but a somewhat altered version to extend the available data did not run successfully at Aberdeen and insufficient information was sent back to get it corrected. A new tape will be sent out.

David Clutterham will go to Aberdeen on April 22 to remain there for several weeks in order to get the shock-wave problem finished. He will also serve as the group representative there during that period and will help in seeing that other problems from the University are tried on the machine.

II CODES WHICH HAVE BEEN WRITTEN OR ARE NOW BEING WRITTEN.

Multiple Precision. A program for carrying out arithmetic operations to precision of about 2^{-75} in addition and division and 2^{-153} in multiplication has been written. It is untested.

Integration. A closed subroutine for evaluating $\int_a^b f(x)dx$ has been written but is untested.

Evaluation of Functions. Subroutines are being written for evaluating functions by means of power series involving Chebychev polynomials. Special attention has been directed toward arctan x using coefficients correct

to 12 decimal places.

Rewriting of Routines. The changes in the order code which make the Illinois machine different from the ORDVAC require rewriting routines. This is being done, and completed routines will be duplicated with flow diagrams and explanatory material for distribution to interested persons.

ORDVAC Manual. The coding group has done a considerable amount of work in preparing diagrams and codes for the ORDVAC manual.

Test Routines. The leapfrog routine has been rewritten for the Illinois machine so that it can be used in either a 512 word or a 1024 word memory. The read-around test is also being rewritten and is nearly complete.

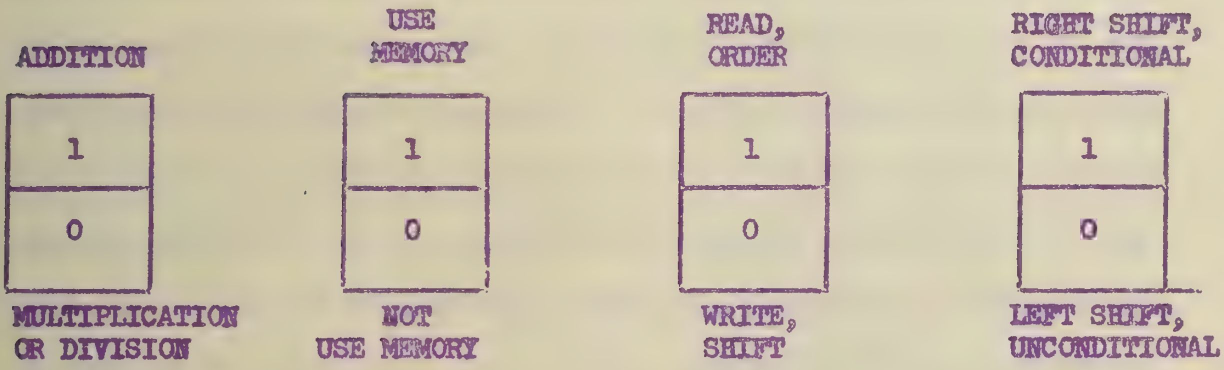
III ORDER CODE FOR ILLINOIS COMPUTER.

The order code will be an eight digit code. It differs in some cases from the code used on the ORDVAC. The code is:

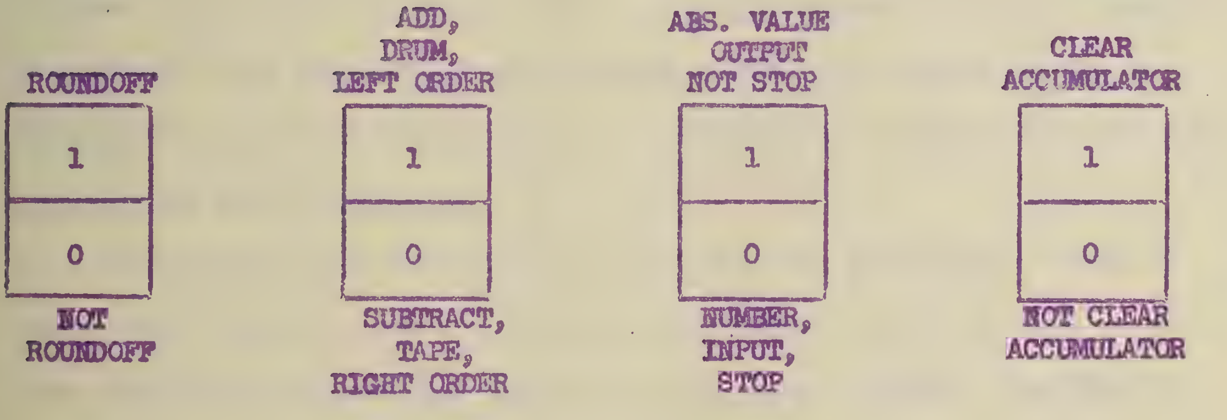
ORDER	INSTRUCTION DIGITS		ORDER	INSTRUCTION DIGITS
Left Shift	00	Uncond. Transfers	Left	26
Right Shift	10		Stop Left	24
Tape Input	80		Right	22
Tape Output	82		Stop Right	20
Drum Input	84			
Drum Output	86			
Letter Output	92	Cond. Transfers	Left	36
Store	40		Stop Left	34
Store Left Address	46		Right	32
Store Right Address	42		Stop Right	30
Memory to Quotient Register	50			
Divide	66		Add from Quotient Register	Sx
Multiply Holding	74		Unconditional Stop	0F
Multiply Unrounded	75			
Multiply Rounded	7J			
Add Orders	Lx			

The functions of the instruction digits are given below.

FIRST SEXADECIMAL DIGIT



SECOND SEXADECIMAL DIGIT



This order code, which is considerably more simple and compact than that used on the ORDVAC, requires some circuit design changes, notably in the decoding chassis. Preliminary design work is now complete and drawings are being prepared for final drafting.

IV MEMORY

Forty-eight memory chassis have been built and tested. The memory frame has itself been built and most of the difficult wiring on it has been finished. Some power wiring remains to be done and some small parts still need to be added. The address generator is currently being built. The address generator will be different from our previous address generator, in that it will have only one input which will come from the center row of flipflops of the dispatch counter. The address portion of an order (which in the ORDVAC entered the address generator) will now be gated into the center row of the dispatch counter. A switch will be provided in the address generator so that the memory capacity can be reduced to 512 numbers when this is desirable for read-around reasons. A switch will be provided in the high voltage bleeder to provide a marginal check when the memory is being adjusted so that when the intensity is low, flaws can be examined, and when the intensity is high, the read-around can be examined.

Two sample tubes have been obtained from the IBM Company. Each of these tubes seems to have a read-around performance about the same as the best 3KP1's we have obtained and seems to be free of flaws. Two 3VP1's made by RCA, but otherwise made to the same specifications as the IBM tubes, have been ordered. Quantities of these tubes are not yet available. The memory is so designed that these tubes could be used without any alteration, except adjustments of intensities and focus and adjustment of the raster size.

One-hundred 3KP1 tubes have been received recently, twenty-four of which have been loaned to Ballistic Research Laboratories. The rest of these tubes will be tested for flaws and read-around ratio as soon as the work of testing the memory chassis has been completed.

In order to implement the memory testing program another Williams test rack will be built. The control circuits for this have been designed but not built. They will make it possible to test read-around at every address of each tube under test automatically.

A 5UP1 tube will be mounted on the computer as a slave tube for the memory. A 40 position switch will make it possible to look at the information on any one of the 40 cathode ray tubes. A second 5UP1 cathode ray tube will be installed in the computer to observe the video signals from each of the 40 chassis through a second 40 position switch. The video signals will be obtained from a 10-ohm resistor in the cathode of the fourth tube of each video amplifier. These signals (which will be about 0.08 volts in amplitude) will be amplified by an amplifier in the circuits with the 5UP1 test tube.

V INPUT-OUTPUT

Provision is being made in the machine so that in addition to the usual input and output orders which we have had in the past there will be available: (1) An output order which will be special and will permit punching all five holes on the teletype tape from the address portion of that special output order, (2) Input and output orders for a magnetic drum to and from R_1, in which the actual order will use forty binary digits

instead of the usual twenty, the last fourteen digits of which will specify the address on the magnetic drum.

VI ARITHMETIC UNIT

The end connections on the new machine have been made to agree with Drawing 396 which provides for the new left shift order. The machine was tested to see that these changes worked satisfactorily.

A chassis was installed to make it possible to test the orders by order pairs and every order in the machine has been tested by order pairs and has been tested from both left and right-hand order positions.

VII CONSTRUCTION WORK

1. Forty-eight memory chassis have been wired to date.
2. Address generator has been assembled and partly wired.
3. A write and counter control circuit, and a manual address circuit have been assembled for testing the new 40 digit memory.
4. The memory frame has been completed and about two-thirds wired.
5. The electrical connections to the arithmetic unit have been removed preparatory to moving the computer for the ventilation duct work.

R. E. Meagher.

R. E. Meagher

REM/nrh

UNIVERSITY OF ILLINOIS
UNIVERSITY RESEARCH BOARD
ELECTRONIC DIGITAL COMPUTER

TECHNICAL PROGRESS REPORT

April 15, 1952 - May 15, 1952

TECHNICAL PROGRESS REPORT

I ORDVAC MANUAL

During the last month a number of corrections have been made to the ORDVAC manual. It is now ready for printing. At the present time we are waiting for suitable quotations so that an order can be placed for 100 copies for the Ballistic Research Laboratories and perhaps 500 copies for the University. We expect to have the manual produced in two editions. One of these editions will be a single volume edition containing all of the material; the second edition will be a two volume edition in which the circuit diagrams will be sectioned off as the second volume of the two volume set. The two volume edition makes it possible to use the text by itself or the circuit drawing section by itself and also makes it possible to refer to one of the circuit drawings while the text is being studied.

II THE USE OF THE ORDVAC

David Clutterham is still at Aberdeen and has succeeded in getting the shock-wave code to run in part. The machine is being used by Clutterham for University problems for 30 to 40 hours per week between 5:00 PM and Midnight each day. Besides the shock-wave problem, he has placed on the machine programs for the Civil Engineering group, for the Psychology group, and the codes which are being worked on by members of our own coding group.

A Teletype machine has been installed here which can be used to transmit codes to Aberdeen by means of the TWX system. As a test, the Decimal Order Input Routine was sent twice on May 16th. After the

transmission we asked the group at Aberdeen to return the code and both transmissions agreed exactly with our master tape. On May 17th a new code for simultaneous equations was sent unsuccessfully the first time because of some switching difficulty at the Aberdeen end. The improved version of the eigenvalue code was then sent and returned and showed no error when checked, and subsequently the simultaneous equation routine was sent and returned for a check. On both checks the agreement was exact. We then received the results of Carlson's 109 and 110 problems by means of the Teletype system, although Clutterham had to cut the tapes by hand at Aberdeen because a reperforator was not connected to the ORDVAC. The Teletype system seems to be very successful for the transmission of these codes.

III CODING AND PROGRAMMING

The code for the Illinois machine has been written up in a formal way and distributed.

An internal report on the calculation of eigenvalues and eigenvectors for a symmetric matrix has been written by Gregory and Wheeler and has been distributed to a limited number of people. This report is quite complete, describing in detail not only the method used, but giving the necessary tape makeups with instructions on how to use the 4 subroutines required. These subroutines, the decimal order input, the decimal number input, a square root, and a decimal print have also been duplicated and can be distributed to anyone interested.

Gregory has written an improved version of the eigenvalue code which is now complete except for the final checking of errors.

The code is now completely automatic. It contains an overall test on the accuracy of the computation which is made at the end of each iteration, and it contains a convergence test. It prints a number indicating the number of iterations required for convergence. At present the tape seems to run through the ORDVAC properly and prints automatically, but the results do not appear to be correct.

Best has continued his work on the preparation of test routines for the university machine. The read around test is now complete, and some minor alterations have been made in the decimal order input. He is now working on the Chebychev expansion for ln (1+x). The routine which he is writing will evaluate (ln y)/32 for y in the range between 0 and 1.

King has finished the arctangent subroutine for both machines and has written a code checking routine for testing it on the ORDVAC. He is now working on a post-mortem routine for the university machine.

Tross has written a code for finding the real zeros of a polynomial, using the device of finding them one at a time and reducing the order of the polynomial after each root has been found.

IV WILLIAMS MEMORY

The memory for the Illinois machine has been assembled and is now ready to be turned on. At the present time the only work that remains consists in fitting the shields to the chassis so that they are interchangeable from one plug position to the next. The test scopes consisting of a five inch slave tube and a five inch oscilloscope for examining the video signals from each of the chassis are mounted on a

relay rack adjacent to the memory rack. In the final machine these test oscilloscopes will be mounted in the arithmetic unit below the memory.

In the last two months about 132 commercial 3KP1 tubes have been tested for possible use in the memory. The procedure consisted in testing the tubes first for flaws and then for read around ratio. In the flaw test a full raster (1024) of dashes was stored and the raster was then slowly moved both up and down and left and right until every point of the surface of a tube was required to store a dash. The number of spots which would not store a dash was noted and recorded on a tag attached to the tube. If the number of spots which would not store a dash (flaws) was greater than five no further test was made of the tube. If the number of flaws was equal to or less than five a read around test was performed at four test addresses as follows: 256, 280, 495 and 1023. The number of tubes now available with one or zero flaws and with a read around of more than fifty at the four addresses is 53.

Circuits are designed and will be built so that this tube test set-up can test the read around at every address successively. These circuits are not yet built.

Two more experimental tubes have been received from the IBM Company, one of which has the P5 phosphor which is believed to provide a somewhat larger output signal. A report will be written on the four IBM tubes which we have received.

V MAGNETIC DRUM MEMORY

Test circuits have been connected up for use with the

magnetic drum. Three channels are currently in operation using signals of the return-to-zero type of recording. One channel has a single index marker, the second channel has 1600 address markers, and the third channel is being used for test recording purposes. Since we are intending to use the drum with a greater pulse density than that used some time ago on the one inch test drum, these experiments are being carried out.

VI ARITHMETIC UNIT

Holes have been cut in the floor so that the cooling system can be added at a later time without disturbing the arithmetic unit. The arithmetic unit is now in place in its final position and will be connected up very soon.

R. E. Meagher.
R. E. Meagher

REM/nrh

UNIVERSITY OF ILLINOIS

UNIVERSITY RESEARCH BOARD

ELECTRONIC DIGITAL COMPUTER

TECHNICAL PROGRESS REPORT

June 15, 1952 - July 15, 1952

I ORDVAC MANUAL

Copies of the ORDVAC Manuals were received from the printer on July 3, 1952. One-hundred copies have since been sent to Ballistic Research Laboratories, one-hundred copies have been sent to L. N. Ridenour and about fifty copies have been distributed to members of the university and to other institutions which we thought would be interested in the description of the ORDVAC.

II USE OF ORDVAC

The ORDVAC has been used to check the corrections of: the integration routine, arctangent routine, code checker routine, solve a set of 25 simultaneous equations using routine 24, and to check the eigenvalue routine with convergence.

The machine has also been used to find the eigenvalues and eigenvectors for two 30 x 30 and two 25 x 25 matrices for the Psychology Department.

III CODING AND PROGRAMMING

In the past month several new programs have been added to the subroutine library. These are:

28.	Decimal order print	(Illinois)
29.	Integration routine for definite integrals	(ORDVAC)
30.	Arctan x	(ORDVAC)
31.	Arctan x	(Illinois)

32. Post mortem checking routine (Illinois)
33. Arctan code checker (ORDVAC)
34. Complex numbers (Illinois)
35. Sequence checker (Illinois)
36. Leapfrog (Illinois)

An eigenvalue and eigenvector matrix program has been written for the Illinois machine and is being prepared for duplication. A floating point double precision routine and a routine for solving Laplace's equations are being coded. A program which will enable the ORDVAC to check codes written for the Illinois machine has been prepared and is now at Aberdeen awaiting test. The following other codes are also now at Aberdeen:

a) Double precision arithmetic
b) Integration check code
c) Theoretical computation (E. E. Department)
d) Test computation (Control Systems Laboratory)
e) Heat flow (M. E. Department)
f) Random walk (Chemistry Department)
g) Complex numbers check
h) Eigenvalue and vectors (Psychology Department)

Members of the M. E. Department, the Physics Department, the Civil Engineering Department and the Psychology Department are now preparing problems for the ORDVAC.

IV MEMORY

Early in the month basic tests on the memory had been finished and an attempt was made to obtain long error-free runs. In the very early part of the month the memory operated on one occasion twenty-three hours and thirty minutes without an error and since that time it has operated several times for intervals of fourteen hours without error. However, the memory is not yet operating sufficiently well to justify moving it to the computer room.

On a number of occasions failures have been noted during the month and the causes of some of these failures have been eliminated. Three badly soldered joints called "rosin joints" have been found, a filament burned out in the high voltage power supply, and a failure was found and corrected in a joint in the high voltage cable. Although these troubles were undoubtedly responsible for errors, some errors persisted after they were corrected. It has been determined that the auxiliary test rack containing the slave tubes has not been adequately grounded and shielded. This is the trouble which has been most recently corrected and additional long runs will now be attempted.

V INPUT-OUTPUT

During the month certain input-output circuits have been installed in the main computer rack or in association with it. These include:

1) Photoelectric tape reader control, drawing #434

2) Input-output shift control, drawing #409

3) Photoelectric tape reader output chassis, drawing #432

4) High-speed punch chassis, drawing #435

The photoelectric tape reader made by the Ferranti Company has been made to operate with the aid of the circuits listed above and has successfully put information into RI, reading either one sexadecimal digit per word or as many as ten sexadecimal digits per word. It has been operated including starting and stoping for periods of several hours after it was made to work satisfactorily. When running full speed the tape is in position for reading approximately three milliseconds and is between reading positions approximately one millisecond. We are currently operating the tape reader so that the brake is applied to the tape as soon as the last sexadecimal digit leaves the reading position (i.e., the brake is applied as soon as the sprocket hole becomes dark after reading the last sexadecimal digit required by the control of the machine). It is clear that with this arrangement a computation time of as much as three milliseconds is available without reducing the speed with which the tape is handled by the tape reader. The Ferranti tape reader has had its circuits altered and now contains U. S. phototubes (5583) and U. S. cathode follower tubes (6AK5). The tape reader operates at a speed of about 240 characters per second.

Of the circuits listed above the high-speed punch output circuit has not been tested. It is expected that this circuit will

be tested with the high-speed punch in the near future. The other three circuits have been tested and are believed to be satisfactory.

VI ARITHMETIC UNIT

The arithmetic unit was tested on June 19th as follows:

8:15 PM to 10:20 PM	Pattern "D" ran error-free
10:35 PM to 11:25 PM	Order Pair "Clear Multiply" and "Divide" for two random numbers. No change in numbers.
11:27 PM to 11:42 PM	Order pair "Right shift K" and "Left shift K". With all 1's in R_1 and R_2. No error.
11:42 PM to 11:55 PM	Same order pair with all 0's in R_1 and R_2. No error.

On July 7 the position of the end connection tubes J15, 16, 17, 18, 19 and 20 were altered. A brief test was made after this change to see that it would not affect the operation of the arithmetic unit.

It has not been possible to run the arithmetic unit more than an hour or so at a time because of the hot weather and the fact that no cooling equipment of any type is now connected to it. The arithmetic unit operated a total of fourteen hours during the month. No tube failures occurred.

VII CONTROL

All the control circuits for the machine have been finished

and checked for wiring errors. The dispatch counter, the memory control, the memory synchronization chassis, and the register selection chassis are waiting to be installed in the machine.

VIII CONSTRUCTION WORK

During the month the construction work has consisted mainly of:

1) Completion of the construction of the several control chassis and input-output chassis.

2) Construction of the frame work for the covers for the machine.

3) Partial construction of a new high voltage power supply for the memory.

4) Tests of tubes.

R. E. Meagher
R. E. Meagher

REM/urh

UNIVERSITY OF ILLINOIS

UNIVERSITY RESEARCH BOARD

ELECTRONIC DIGITAL COMPUTER

TECHNICAL PROGRESS REPORT

July 15, 1952 - August 15, 1952

I USE OF ORDVAC

During the past month the following staff members from the University have been at Aberdeen:

Brooks, John
Civil Engr. Department
Arrived August 1 - Returned August 13

Gillies, D. B.
Computer Department
Arrived August 1

Neuhaus, Jack O.
Psychology Department
Arrived July 15 - Returned August 1

The ORDVAC has been used for the solution of a heat flow problem, a problem in structures and for control (CSL) calculations. It has also been used to check codes written for the Illinois machine by use of an interpretive program which will execute orders in the way the Illinois machine will carry them out. The double precision arithmetic routine has been checked on the ORDVAC and is now being prepared for duplication.

Because of machine difficulties and an increased work load put on the machine by the BRL staff the amount of available time has been much diminished. Use of the Teletype connection between Aberdeen and the Computer Laboratory has materially aided in the running of programs. Errors have been very few in number and codes are now handled smoothly at both ends.

II CODING AND PROGRAMMING

Several new programs have been added to the library in the past

month. These are listed below:

37.	Print one number in a parameter-set layout	(ILLINOIS)
38.	Address search routine	(ILLINOIS)
39.	Full printing checking routine	(ILLINOIS)
40.	Integration of f(x) given at equal increments of x	(ILLINOIS)
41.	Second supplement to Code 17 (for printing eigenvectors)	(ORDVAC)
43.	Natural Logarithm	(ILLINOIS)
44.	Read-around Test	(ILLINOIS)

The Computer Laboratory is now giving advice to members of the Physics Department and the Business Organization and Operation Department in the solution of an eigenvalue differential equations system and in the evaluation of marketing data respectively.

One program for solving Laplace's equation has been written and is being checked. A program for fitting a least squares line is also ready to be checked.

III COURSES OFFERED

Two courses will be offered for the Fall semester as follows:

Math 385 - Theory of High-Speed Computing Machines
9:00 AM, Monday, Wednesday and Friday
Dr. David J. Wheeler

Math or E. E. 384 - Logical Design of Automatic Digital
Computer Circuits - 10:00 AM, Monday, Wednesday and Friday
Dr. J. E. Robertson

IV MEMORY

At the beginning of the month two troublesome difficulties which had prohibited previous long memory runs were eliminated. These were:

1. The grounding and shielding of the temporary oscilloscope rack was inadequate, and
2. The high-voltage supply had occasional break-downs which caused dots to change to dashes in the outer areas of the memory pattern.

The memory was finally operated from 12:30 AM, August 1st to 8:00 AM, August 2nd with one error due to a flaw and no other errors and then from 1:00 PM, August 2nd to 8:00 AM, August 4th with no errors at which time the memory was voluntarily turned off. Our present group of 40 cathode ray tubes used during these tests contain 20 tubes with one or more flaws as checked August 4.

The memory was subsequently moved from the test room, mounted on top of the arithmetic unit and since that time the main work of the group has consisted in connecting it to the arithmetic unit. Testing of the memory circuits has been started and so far it has been shown that one test position can store dots or dashes. Long runs on the memory will require that the air-conditioning unit be finished, and the date when this will be so is not known.

We are trying to obtain additional information on the availability of improved cathode ray tubes.

V INPUT-OUTPUT

The punch which operates at a speed of 25 characters per second has been placed into operation with its circuits which are shown on Drawing 435. This has operated satisfactorily for brief periods of time, but no long runs have as yet been carried out.

VI ARITHMETIC UNIT AND CONTROL

The following control circuits have been installed with the arithmetic unit:

Dispatch Counter	Drawing 274
Memory Control	Drawing 428
Memory Synchronization Control	Drawing 429
Register Selection Chassis	Drawing 427

The carry propagate and carry collapse times had been unbalanced in the adder and these have been measured and corrected. The +104 volt bus in the adder is now connected to a point on the bleeder labeled 102 volts but which measures 100 volts. With this connection the carry propagate time was measured as 9.2 microseconds and the carry collapse time has 9.4 microseconds. The present setting of the carry delay multivibrator is 9.2 microseconds. Certain RF oscillations were removed from several of the buses in the arithmetic unit, by the addition of 0.01 mfd condensers.

Operation times in the machine were measured as follows

Addition -	39.5 ± 3 microseconds
Add and operate -	49.5 ± 3 microseconds
Divide and operate -	1000 ± 30 microseconds
Multiply and operate -	
with all 0's in the multiplier	610 ± 20 microseconds
with all 1's in the multiplier	1010 ± 30 microseconds

There were four tube failures during the month, two of which were in the +100 volt power supply. The arithmetic unit was operated a total of 47 hours, a large fraction of which consisted in carrying out addition test problems and multiplication pattern D. After the carry propagate and collapse times were checked there were no errors on either the addition tests or pattern D except on one occasion when pattern D failed. No explanation is available for that one failure. It will be checked again.

VII CONSTRUCTION

A set of temporary covers for the computer has been finished and the memory has been installed and connected into the arithmetic unit.

R. E. Meagher

R. E. Meagher

REM/cmb

DIGITAL COMPUTER

TO: Executive Committee, Computer Subcommittee,
Graduate College

FROM: R. E. Meagher

DATE: September 24, 1952

Since our own computer is now in an operating condition we have stopped sending problems to Aberdeen to be put on the ORDVAC. The last problem for the ORDVAC was sent on August 28th and results for this were returned on September 5th. The TWX unit was disconnected on September 9th. BRL says that we have used the ORDVAC 600 hours since its installation there.

Intended mainly for use during the night hours a telephone has been installed in the computer room. The number of this phone is 3278.

Mr. Theodore Shapin, Mr. E. L. Hughes and Dr. D. J. Wheeler attended a meeting of the Association for Computing Machinery at the University of Toronto, September 8-9.

The cooling system for the computer was first turned on on August 21st. It has operated very satisfactorily since that time. A thermometer installed in the exhaust air duct indicates that the temperature of the computer is kept relatively constant.

This should aid somewhat in reducing the adjustments of the memory.

For the work of the group I believe that it will be necessary to purchase two additional large power supplies from the Power Equipment Company amounting to about $7,500 and additional Teletype equipment which may amount to about $3,300. I am taking steps now to obtain the necessary quotations for these.

Now that our own computing machine has been placed into operation I believe that it will be possible to turn the attention of some fraction of the group to problems of a research nature as contrasted to the constructional problems of the past. Some developmental work and a considerable amount of construction work will, however, be necessary on the magnetic drum. It will be desirable to transfer the salaries of Mr. Wier and probably Mr. Liu to the ONR Task 24 contract.

During the month we have had as visitors: Dr. L. N. Ridenour, Mr. Eric Mutch of the University of Cambridge, Mr. Cletus Unger, Institute of Technology, Darmstadt, Mr. Alfred Kuhlenkamp of Germany and Dr. W. S. Elliot and Mr. H. G. Carpenter of Elliott Brothers.

The personnel list of the group is as follows:

Brown, Caroline, Teletype Operator
Butler, William, Jr. Elec. Tech.
Clutterham, D. R. Grad. Res. Asst.
Cobb, Bessie, Grad. Res. Asst. (1/2 time)
Gibson, Margaret, Draftsman (Starting 9/22/52)
Gregory, R. T., Grad. Res. Asst. (1/2 time)
House, Natalie R., Clerk-Steno III
Huffman, William, Computer Operator
Hughes, E. L., Res. Assoc.
Jones, Walter E., Model Maker

Kalapaca, H. P., Student Asst.
Kerkering, T. E., Jr. Lab. Mech.
King, Richard, Grad. Res. Asst. (1/2 time)
Kudlich, R. A., Grad. Res. Asst. (1/2 time)
Leichner, G. H., Grad. Res. Asst. (1/2 time)
Liu, R. C., Asst. Lab. Mech.
Lopeman, H. E., Sr. Elec. Tech.
Meagher, R. E., Chief Engineer
Michael, G. W., Admin. Asst.
Muller, David, Univ. Fellow
Nash, J. P., Res. Prof. of Applied Math
Robertson, J. E., Res. Asst. Prof. of E. E.
Russell, Ramona, Computer Operator
Shapin, Theodore, Res. Assoc.
Taub, A. H., Res. Prof. of Applied Math
Wier, J. M., Res. Assoc.
Wheeler, D. J., Visiting Asst. Prof. of Math

A financial statement prepared by Mr. Michael is attached.

R. E. Meagher
R. E. Meagher

REM/nrh
Enclosures

FINANCIAL REPORT
AS OF

September 15, 1952

	DIGITAL COMPUTER	U.S. TASK 24	U. S. TASK 30	INDIRECT COST COMPUTER	ENGR.RES. LAB. COMPUTER	COMPUTER REVOLVING	TOTAL
EQUIPMENT				11,570.09			11,570.09
MATERIALS	1,515.25	6,771.61		39,820.57	47.85		48,155.28
SALARIES	5,142.36	9,982.06	10,235.82	45,805.25		2,183.69	73,349.18
OVERHEAD		4,033.86	4,062.31				8,096.17
WORK. COMPEN.		139.13	28.00				167.13
RETIREMENT	265.00			2,727.23		165.00	3,157.23
TRAVEL	58.40	362.09		2,017.23			2,437.72
TELE-TELEG.	4.00			673.98		566.50	1,244.48
BUILDING-MOVING ARCH. FEES				1,874.25	750.00		2,624.25
	6,985.01	21,288.75	14,326.13	104,488.60	797.85	2,915.19	150,801.53

ACCOUNTS CLOSED-OUT:

(U. S. Ordnance 680	12,307.65
(U. S. Ordnance 11362	250,000.00
(Elec. Digital Computer	75,000.00
(Grad. Res. Computer	20,000.00
(Indirect Cost-Math.-Taub	8,150.00
TOTAL EXPENDITURES.....	516,259.18

Prepared by: G. W. Michael
Admin. Asst.

UNIVERSITY OF ILLINOIS

GRADUATE COLLEGE

DIGITAL COMPUTER

TECHNICAL PROGRESS REPORT

August 15, 1952 - September 15, 1952

I CODING AND PROGRAMMING

The completion of the Illinois machine has permitted the checking of the Illinois read-around and "leapfrog" test routines, and a systematic check of the library routines has been begun.

The eigenvalue code (No. 42) has been tested and put into the library. A second such program which finds eigenvalues of a symmetric matrix by selecting the largest off-diagonal element rather than by choosing elements in sequence has been machine checked.

A complex numbers program was machine tested on both the ORDVAC and the Illinois machine.

Clutterham has been assisting Lee of the Physics Department in the solution of a set of Schroedinger equations by a relaxation method. The solution involves four parts: (1) computation of trial functions, (2) computation of the energy, (3) relaxation of the net, and (4) computation and printing of moments. Thus far (1), (2) and (4) have been checked out.

Other codes will be checked out on the Illinois machine and a list of those finished will be given in the next report.

II ILLINOIS COMPUTING MACHINE

After a considerable period to complete the connections between the memory and the arithmetic unit the memory stored statically from 8:15 AM August 26 to 12:15 AM August 27. This was considered to be

reasonable evidence that the memory did not have a large source of static errors and the connections of the memory interplay control were then completed. The machine first operated as a unit on August 28 and the succeeding three days were spent in eliminating some final errors in the read-around routine and the leapfrog routine. On Sunday, August 31 the machine computed the base of the natural logarithm to 2270 decimal places according to a code written by Gillies. A spot check of e indicated an agreement with previous results obtained from the ENIAC. On September 1 e was calculated to 4880 decimal places.

The machine operated the leapfrog routine from 8:50 PM September 10 to 5:01 AM September 11 and again from 11:20 AM September 12 until 7:56 PM September 12. The routine was stopped voluntarily after each run. Typical performance for the read-around ratio at 1024 and 512 digit rasters can be seen in the following table (the number of failures listed is the sum of separate failures after four tests):

Read Around Test	1024 Raster No. of Failures	512 Raster No. of Failures
5	0	0
10	0	0
15	0	0
20	3	0
25	12	0
30	-	0
40	-	0
50	-	1
60	-	2
70	-	4
80	-	1

At the present time the input for the machine can be obtained from a photoelectric tape reader or from the Control Systems Laboratory, and output from the machine can be obtained from the high speed punch, or from a Teletype page printer (at standard speed).

The largest source of errors in operating the machine so far has been due to flaws on the cathode ray tubes. At the present time about twenty of the cathode ray tubes are believed to be free of flaws but another twenty cathode ray tubes have a total of about thirty flaws. At the present time an adjustment is made of the raster position on all tubes in an effort to dodge as many of the flaws as possible. The remaining flaws are eliminated by placing small magnets near one or two cathode ray tubes. It has been necessary to change these adjustments on a number of occasions indicating that we may have some drift in the voltages being applied to the deflection plates of the cathode ray tubes. This will be examined in the near future.

Additional work which needs to be done on the machine of an engineering nature is (1) make a final set of measurements of the operation times within the machine, (2) make a cover for the high speed punch to reduce noise, (3) lace the wires in the memory interplay control, (4) investigate the tolerances of the A and B voltages from the punch, (5) ascertain the reason for the drift in voltages of the +100 volt power supply and (5) install a final set of covers.

For the very near future it is anticipated that the machine will be on between 8:00 AM and midnight, Mondays through Fridays. Generally, the periods between 8:00 AM and 12 noon will be used for adjustments and engineering work outlined in the preceding paragraph, the period between 1:00 and 2:00 will be used for the checking or running of short routines, and the rest of the time will be available insofar as possible for useful problems.

The machine has been operated approximately 410 hours to date and 25 tubes have failed during this period of time.

R. E. Meagher
R. E. Meagher

REM/nrh

DIGITAL COMPUTER

TO: Executive Committee, Computer Subcommittee and Graduate College

FROM: R. E. Meagher

DATE: October 29, 1952

During the last month a rather appreciable fraction of the group's effort has been placed upon the general problem of getting the machine running well and on a regular schedule. The machine is now on a regular schedule allowing its use from noon until midnight, Mondays through Fridays. Some measurements and alterations will, of course, be desirable from time to time and the most important of these are: (1), the installation of a final set of covers and, (2), the speedup of addition by eliminating the left shift in the addition process. The feasibility of installing the new covers is under debate.

Mr. E. L. Hughes will resign effective December 1, 1952. Mr. Kalapaca, a student assistant, is no longer working with us. The personnel list, except for these comments, remains the same as the one presented in the September 15th report.

An effort has been made to close out the Graduate Trust-Indirect Cost-Computer-Meagher account. This has been approaching the figure of $105,000, but this is $5,000 more than was actually put into this account

by the Research Board. The discrepancy is due to a misunderstanding which dates back some time ago. The financial statement prepared by Mr. Michael is attached.

R. E. Meagher

R. E. Meagher

REM/nrh
Enclosures

Digital Computer Laboratory
University of Illinois
FINANCIAL REPORT
As of: OCT 15 1952

	Digital Computer	U. S. Task 24	U. S. Task 30	Indirect Cost Computer	Engr. Res. Lab. Computer	Computer Revolving	TOTAL
Equipment	141.49			11,649.62			11,791.11
Materials	3,269.57	8,766.61		40,056.48	460.93		52,553.59
Salaries	13,662.96	11,091.22	10,835.82	45,805.24		2,748.70	84,143.94
Overhead		4,468.36	4,269.11				8,737.47
Work Compen.		124.83	170.56				295.39
Retirement	641.02	55.18		2,679.63		213.12	3,588.95
Travel	58.40	362.09	297.19	2,241.55			2,959.23
Tele-Teleg.	29.25		69.05	693.23		569.60	1,361.13
Building-Moving Arch. Fees				1,874.25	4,010.00		5,884.25
	17,802.69	24,868.29	15,641.73	105,000.00	4,470.93	3,531.42	171,315.06

ACCOUNTS CLOSED-OUT:

(U. S. Ordnance 680	12,307.65
(U. S. Ordnance 11362	250,000.00
(Elec. Digital Computer	75,000.00
(Grad. Res. Computer	20,000.00
(Ind. Cost - Math Taub	8,150.00
Total Expenditures:	536,772.71

Prepared by: G. W. Michael
Admin. Asst.

UNIVERSITY OF ILLINOIS

GRADUATE COLLEGE

DIGITAL COMPUTER

TECHNICAL PROGRESS REPORT

September 15, 1952 - October 15, 1952

I MATH GROUP ACTIVITY (This is supported in part by ONR Task 30).

A number of new programs have been added to the library and a systematic check of library codes has been carried out. The machine tested library codes for the Illinois machine are now as follows:

TABLE I

CODE NUMBERS	
18	Decimal Order Input
21	Square Root
23	Decimal Number Sequence Input
25	Single Column Print
27	System of First Order Differential Equations
28	Decimal Order Print
31	Arctangent
35	Sequence Checking
36	Leapfrog
37	One Number Parameter Layout Print
38	Address Search
39	Full Printing Check Routine
40	Integrate f(x) at Equal x Increments
42	Eigenvalues and Eigenvectors
42.1 42A 42B	Modifications in printing, iterating and testing for convergence
43	Natural Logarithm
44	Read-Around
47	Simultaneous Linear Equations
48	Post Mortem
49	Staggered Raster Read-Around
50	Complex Arithmetic
51	Automatic Linear Equations
52	Print One Decimal with or without sign
53	Print one Integer with or without sign
54	Tape Lettering
55	Same as 53 but suppress zeros on the left

There are still some library codes which have not been machine checked. One of these (No. 46) is a floating decimal routine previously listed as checked. Another is a double precision routine (No. 45). These codes are important ones and will be checked at once.

Code 51 simplifies greatly the solution of n simultaneous linear equations. It is essentially a combination of Codes 18, 23, 25 and 47, and will handle up to n=39 equations. Only one parameter need now be set. After the program is read in, the data tape with coefficients scaled to less than 1/2 is put in the reader. On the end of the data tape is punched one character giving the number of decimals to be printed. This is the lone parameter. The program determines n by counting coefficients, solves the equations, and punches the results.

A number of computations of e have been carried out to several thousand decimal places. At present two different codes (using different methods) have given identical results to 8,000 decimal places. One code for e has been written which is fully checked against single computational errors (including input and output) and we expect to use machine time as it is available to compute about 50,000 places. This will give us valuable data on machine operation in a large scale computation.

Several checked variations of Code 42, the fundamental eigenvalue-eigenvector codes have been completed. These variations are:

(a) Code 42.1 is a new set of punching instructions which make it possible to use the output tape as an input tape. It is used with (d) on the next page.

(b) Code 42A uses a convergence test different from that of Code 42 and counts orthogonal transformations rather than iterations.

(c) Code 42B is a modification of 42A and selects the largest off-diagonal element rather than elements in sequence.

(d) A routine has been written which checks the eigenvalues and eigenvectors and prints residuals defined by $R=(AX)/\lambda-X$. This will be rewritten to define residual as $R=AX-\lambda X$.

At present one 8 by 8 matrix has been used with all of the above routines. An analysis is being made to compare the codes a, b, and c.

Several demonstration tapes have been written.

Work is continuing on the shock wave refraction problem.

II USE OF THE COMPUTER

A. Table II shows the distribution of machine time for the interval September 16 through October 15.

TABLE II

Engineering time during the intervals 8AM-12N and 4:30PM-5:00PM (excluding the running of flew, RAR, and leapfrog tapes)		59h	59m
Repairs at other periods of the day		34	52
Wheeler	(1)	37	49[x]
Nash	(1)	9	18
Robertson	(6)	13	02
Leichner	(0)	5	39
Clutterham	(0)	6	39
King	(0)	2	49
Gregory	(1)	6	42

[x] About 15 hours of this was for Chemistry, the rubber molecule problem (Wall).

Cobb	(0)	1	15
Others in Computer Lab	(0)	6	31
Physics, (Lee)	(0)	2	56
CSL	(1)	32	55
Civil Eng: Benesch	(0)	5	09
Civil Eng: Carlson	(1)	6	25
Psychology: Neuhaus	(1)	6	23
Psychology: Wrigley	(0)	3	20
Flaw and RAR	(11)	25	17
Leapfrog	(47)	102	05
Wasted	(0)	3	15
Operator Training	(0)	2	56
Demonstrations	(0)	1	13
	Total:	377	26

The number of errors made by the machine while on the codes listed is given in the parentheses. The total errors so listed in the log for this interval is 70.

This is a breakdown on the use of the machine as prepared from the log by Mr. Huffman.

B. The problems put on the machine for the Computer Group are described in I. Other work carried out on the machine is described here briefly by the groups using the machine.

Psychology (Wrigley). The following tasks were completed:

1. Eigenvalues and Eigenvectors. The eigenvalues and eigenvectors were obtained for seven matrices of order 23 x 23.

2. Matrix Multiplications. Some large matrix multiplications were carried out, eight in which square matrices of order 23 x 23 were multiplied together, one in which a 120 x 23 matrix was multiplied by a 23 x 23 matrix, and one in which a 23 x 120 matrix was multiplied by a 120 x 23 matrix. In each case matrices were partitioned into blocks, since total elements in the multiplying matrices exceeded the storage capacity of the computer. By a series of calculations involving both matrix multiplication and matrix diagonalization, an orthogonal set of factor loadings was obtained for a correlation matrix of order 120 x 120.

3. Transposition of a Matrix. A matrix of order 120 x 23 was transposed to avoid the need for repunching.

4. Code Checking. Programs for the transposition of a matrix and for the conversion of eigenvector elements to factor loadings have been tested.

Chemistry (Wall, Wheeler). In order to investigate the structure and size of psuedo-rubber molecules and obtain statistics on their root-mean-square lengths, a large sample of such molecules was surveyed. Each "molecule" was constructed of a chain of "atoms", each bond being of unit length and perpendicular to the preceeding bond. Thus at each stage there were four possible positions for the new "atom". The choice was made using psuedo-random numbers. Statistics were obtained on molecules of 1 to 100 units for a few million specimens. The structure of a second type of molecule is to be investigated.

Civil Engineering (Benesch, Carlson and Brooks). Two sets of simultaneous non-linear differential equations of second order have been solved. The equations are the equations of motion of a system of masses and their connecting structural elements. They are of the form:

$$\ddot{y}_i = f_i \left(y_j(t),\ \dot{y}_j(t),\ y_j(t-\lambda),\ \dot{y}_j(t-\lambda) \right) + q_i\ (t)$$

$$i = 1, 2 \ldots n$$

$$j = 1, 2 \ldots n$$

Initial conditions $y_i(0)$ and $\dot{y}_i(0)$ are specified. The solutions are for an interval, $\lambda \leq t \leq T$, where λ is small compared to T, and the two solutions which have been obtained are for $n = 18$.

Physics (Lee, Clutterham). An attempt was made to find the 4 eigenvalues for a set of 4 Schroedinger equations. The work was not finished.

CSL. This required computations of a control nature which are under security classification.

III ERROR FREQUENCY AND PERFORMANCE

The machine is normally used for "engineering" and maintenance between 8AM and 12N, and for a check of its performance between 4:30PM and 5:00PM of each weekday. Since the periods between 8 in the morning and noon, together with certain other irregular periods like Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more instructive from an error analysis standpoint to look at the periods between noon and midnight of each weekday in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind a summary table has been prepared using the period between noon and midnight of each weekday. This table lists the running time when the machine was operating properly, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. Each failure was considered to have terminated a running period and was followed by a repair period to be consistent in the method of preparing this table. Since the leapfrog code is very probably our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented as Table III.

TABLE III

	RUNNING OK	REPAIRS	AIR COND. REPAIRS	FAILURES DURING OK TIME	LEAPFROG	FAILURES ON LEAPFROG	WASTED
16	4:47	6:46	0	3	3:35	3	:27
17	1:19	8:47	0	3	1:08	3	1:54
18	10:36	1:03	0	3	5:09	2	:21
19	6:16	5:04	0	0	:42	0	:40
22	11:04	0:40	0	2	5:18	2	:16
23	7:19	4:25	0	0	3:02	0	:16
24	6:45	5:05	0	0	4:24	0	:10
25	11:24	:26	0	1	3:54	1	:10
26	9:13	2:16	0	3	4:34	3	:31
29	8:32	3:13	0	4	5:20	4	:15
30	5:56	5:56	0	2	2:38	0	:08
1	11:15	:45	0	1	3:38	0	0
2	11:35	:25	0	1	4:10	1	0
3	11:21	:29	0	2	4:49	1	:10
6	11:50	0	0	0	3:33	0	:10
7	11:07	:53	0	2	1:06	0	0
8	9:18	1:43	:59	3	1:14	0	0
9	10:51	0	1:09	1	1:41	1	0
0	11:29	:31	0	4	1:17	2	0
3	6:51	5:09	0	1	1:13	1	0
4	8:20	3:40	0	2	3:38	2	0
5	11:27	:25	0	1	4:28	0	:08
	198:35	57:41	2:08	39	70:31	26	5:36

It may be seen from this Table that the machine operated on problems or was available for problems about 75% of the time during the interval. During this 75% period (198 hours) a total of 39 errors occurred; 26 of these errors were associated with the leapfrog routine which was operated a little over 70 hours. It may be observed from Table III that for the period October 1 through October 15 the machine was operating 87% of the time or about 116 hours and the number of errors for this period was 18.

The machine has been operated about 770 hours. It has been in operation as a complete unit since about September 1.

IV COMMENTS ON THE MACHINE

A. Memory

During the month the largest single source of failures within the machine has been associated with flaws on cathode ray tubes. This was aggravated by the fact that it is apparently true that the raster moved slightly on at least two occasions so that flaws which had been dodged previously became important. It has been established that a change of a few volts in the -300 volt voltage being supplied the machine can produce a shift with similar results, although it is not known whether or not this was the cause of the two shifts. Steps are now being taken to eliminate this possibility.

The read-around ratio of the memory has been steadily improving. There seem to be two reasons why this might be so. First, the intensity of the cathode ray tubes may have been decreasing somewhat

as a group and this has tended to increase the read-around ratio (and enhance the flaw problem). Secondly, some of the tubes with poor read-aruund ratio have been replaced. A typical read-around table (1024 digit raster) was obtained on October 13th and is shown as Table IV.

TABLE IV

RAR TEST	NO. OF SEPARATE FAILURES AFTER TWO TESTS	NO. OF SEPARATE CATHODE RAY TUBES INVOLVED IN THE FAILURES
5	0	0
10	0	0
15	0	0
20	0	0
25	0	0
30	2	2
40	24	10
50	60	9
60	about 125	14

B. Arithmetic Unit

The arithmetic unit has been checked to see that the line voltages can be changed without affecting the machine. When this was first tried the -300 volt supply could be reduced to only about -302 volts before the arithmetic unit and control would simply stop. No errors occurred. This occurred because of a tolerance problem in the clear driver circuits. It has been corrected in the sense that the -300 volt power supply potential can now change by at least 5% (as well as all of the other voltages except the cathode ray tube voltages).

C. Input-Output

The relay which connected the printer control to the output

teletype circuits was found to be unreliable and has been replaced. The circuit associated with the reading of the sprocket hole for the photoelectric tape reader has been slightly altered for tolerance reasons.

An alteration was made in the input-output shift sequencing chassis, and the "A" gate disc was moved around on the crank shaft of the punch. These changes increased the time available for computation during the punching process from 10 milliseconds to 16 milliseconds. Any further increase in this time could not be made due to the inability of the pawl magnet to release quickly enough.

D. Test Routines

A number of test routines have been written which are available for testing individual parts of the machine. In addition to our standard flaw test, read-around test, and the leapfrog, the test routines listed as Table V are now available.

TABLE V

1. Place Crippled Leapfrog
2. Stripe RAR Test
3. Find Leapfrog and Print Discrepancies
4. Single Digit Adder and Digit Resolver Test
5. Input Routine
6. Glow Worm RAR Test
7. Leapfrog Tape Test
8. Printer Test
9. Switch Controlled Print Routine
10. Plant Address Test Routine

V RESEARCH AND DEVELOPMENT (This is supported in part by ONR Task 24)

An overall scheme has been worked out for attaching the

magnetic drum to the machine. This involves serial storage on the drum using information obtained 4 digits at a time from RI, and uses a buffer register to transfer the information from the four digit parallel system to the serial system. This system has been adopted because it makes possible the efficient use of the storage medium with a non-return-to-zero system. This system should make it possible to store 64 words of 40 binary digits each on each of 200 drum circumferences. Words would be read out one word at a time and a subroutine will be necessary in the machine in order to read out blocks of words. A set of logical drawings for this entire system is now being prepared.

A study of various solid core memories including the ferrites is being made. Orders for samples of these cores have been placed.

A number of 1768 and 1698 transistors have been received (via Army channels). Work can now be started on direct coupled transistor circuits.

The equipment designated as WX is now nearly completed. This is a very general purpose Williams test rack which will make it possible to test as many as 6 Williams tubes simultaneously and to ascertain the performance of the circuits and the tubes individually. Automatic circuits are available to make a read-around test at each of the 1024 addresses of each tube. As soon as this WX is put into operation it will be possible to make any tests on cathode ray tubes

or chassis to keep the main computer operating. It can then be considered to be a service rack in this respect. It will then be possible to use the Williams II memory equipment to carry out a test with a Radechon tube loaned to us by CSL and to use the Williams II memory equipment for other experimental needs.

VI CONSTRUCTION

Construction work carried out during the month has consisted of the following:

1. Finished spare clock for computer (Drawing M-413)
2. Finished spare pulser for computer (Drawing M-414)
3. Finished address generator for WX (Drawing L-403 and Drawing S-395)
4. Finished register for WX (Drawing M-407)
5. Finished RAR and counter control for WX (Drawing L-408)
6. Finished clock for WX (Drawing M-413)
7. Finished 3 pulser chassis for WX (Drawing M-414)
8. Finished Pulse mixing and C. F. Chassis for WX (Drawing M-397)
9. Finished "A" scope amp and sweep circuits for WX (Drawing M-412)
10. Finished reversing control chassis for WX (Drawing M-406)
11. Finished WX frame and covers 7/8 completed
12. Finished checking 600 5687 tubes.

VII REPORTS AND SEMINARS

The following reports have been written during the month:

INTERNAL REPORT NO. 38

Revised Order Code for University of Illinois Digital Computer by J. P. Nash and D. J. Wheeler - 9/23/52

INTERNAL REPORT NO. 39

How to Calculate the Read-Around Requirements of a Code by J. P. Nash - 10/14/52

INTERNAL REPORT NO. 40

Operation Times of the Illinois Computer by E. L. Hughes
10/16/52

The seminars presented during the month have included:

September 16, 1952 - Digital Computers in England by Eric Mutch

September 24, 1952 - A Survey of Matrix Memories Using Solid Core Materials by J. M. Wier

October 1, 1952 - Input-Output Logic by E. L. Hughes

October 8, 1952 - A Magnetic Drum Memory and its Relation to the Present Computing Machine by T. Shapin.

October 15, 1952 - Shock Wave Problems by A. H. Taub

R. E. Meagher
R. E. Meagher

REM/nrh

DIGITAL COMPUTER

TO: Executive Committee, Computer Subcommittee and Graduate College

FROM: R. E. Meagher

DATE: November 26, 1952

Mr. Leichner has been placed in 1-A by his Appeal Board. Mr. Liu is resigning, effective November 25, 1952, to take a position with the University of Minnesota. Except for these two remarks the personnel list associated with this group remains the same as that contained in the September 15th report.

A financial statement prepared by Mr. Michael is attached.

R. E. Meagher.
R. E. Meagher

REM/nrh

Enclosures

University of Illinois
Financial Report
As of November 15, 1952

	DIGITAL COMPUTER	U.S. TASK 24	U.S. TASK 30	INDIRECT COST COMPUTER	DIG.COMP. SPECIAL EQUIPMENT	COMPUTER REVOLVING	TOTAL
EQUIPMENT	141.43			11,680.88	3,354.14		15,176.45
MATERIALS	4,594.31	8,766.61		40,025.22			53,386.14
SALARIES	19,468.65	12,104.55	11,435.82	45,805.24		9,443.70	98,257.96
OVERHEAD		4,865.60	4,504.31				9,369.91
WORK. COMPEN.		145.25	214.56				359.81
RETIREMENT	846.02	53.85		2,679.63		345.16	3,924.66
TRAVEL	68.10	429.10	297.19	2,241.55			3,035.94
TELE-TELEG.	577.65		69.05	693.23		569.60	1,909.53
BUILDING-MOVING ARCH. FEES				1,874.25			1,874.25
	25,696.16	26,364.96	16,520.93	105,000.00	3,354.14	10,358.46	187,294.65

ACCOUNTS CLOSED-OUT:	(U.S. ORDNANCE 680	12,315.96
	(U.S. ORDNANCE 11362	250,000.00
	(ELEC. DIGITAL COMPUTER	75,000.00
	(GRAD. RES. COMPUTER	20,000.00
	(INDIRECT COST-MATH-TAUB	8,150.00
	TOTAL EXPENDITURES.....	552,760.61

Prepared by: G. W. Michael
Admin. Asst.

UNIVERSITY OF ILLINOIS

GRADUATE COLLEGE

DIGITAL COMPUTER

TECHNICAL PROGRESS REPORT

October 16, 1952 - November 15, 1952

I MATH GROUP ACTIVITY (This is supported in part by ONR Task 30).

Using the four codes of type 42 listed in the October report, matrices of order 4, 8 and 12 have been completely evaluated and matrices of order 16 and 20 have been partially evaluated. A discussion of the results was given in a seminar on November 12 and further work will be done. The purpose of the study is to determine the best way of finding eigenvalues and eigenvectors. A code has now been written to generate elements of test matrices, thus avoiding the tedious tape preparation otherwise needed.

The study of programs for partial differential equations is going ahead with attention now being given to the two dimensional Laplace equation.

One of the members of the programming group is studying the problems which will arise when the magnetic drum is attached to the ILLIAC. An example of such a problem is the solution of a set of simultaneous algebraic equations with more than 39 variables, the present maximum number.

A few new programs have been added to the subroutine library. These are:

56. Print decimal address and fraction
57. Print decimal address and integer
58. Consolidated engineering test
59. Print decimal address and order pair
60. Best least squares line

Code 60 is a program for fitting a least squares straight line to a set of $n < 1000$ points.

Codes 56, 57 and 59 are checking routines to aid in analysis of programs.

Code 58 is an integrated test which is now the accepted test for determining the operability of the machine. It contains the following tests:

1. Flaw test
2. Read around test
3. Tape reader test
4. Printer test
5. Punch test
6. Leapfrog test

There are no stops in the flaw test, which tests the entire memory 4 times, unless there is a flaw. Upon failure the faulty address is given in R_2 with the faulty memory tube indicated in R_1. The read around test is as before with failures printed. When the ratio rises above 40 the program goes on to the tape reader test. This test reads sets of complementary words from the tape and prints incorrect pairs. When a marker word occurs the printer test begins. Here the printer is tested for its ability to print alternate K's and 5's, ten digits being printed on each of 64 lines. When the printer test ends, the punch test is read into the machine and the machine stops to allow time to switch the output from PRINT to PUNCH. Then 64 words each containing the sexadecimal characters 0123456789KSNJFL and a carriage return signal are punched. At the end of the punch test the leapfrog is read in and stops as usual before leaping commences.

Code 60 is a program for fitting a least squares straight line to a set of $n < 1000$ points.

An increasing amount of time is being spent in consultation with university staff members and others who are interested in problem preparation. Members of the departments of electrical engineering, mathematics (statistics), chemistry, physics, psychology and civil engineering are now coding problems for the machine.

The students in Mathematics 385 regularly use the machine to test the coding of problems assigned as part of their class work, and the students in Mathematics - E. E. 384 have visited the laboratory in connection with their study of logical machine design.

(continued on page 4)

II USE OF THE COMPUTER

Table I shows the distribution of machine time for the interval October 16 through November 15.

TABLE I

Engineering time, normally occurring during the periods 8-12 AM and 4:30-5:00 PM		26h	59m
Engineering time at other times due to failures		18	01[*]
Wheeler	(6)	36	40
Nash	(0)	1	36
Robertson	(0)	3	44
Leichner	(2)	16	57
Clutterham	(1)	17	23
King	(0)	0	39
Gregory	(1)	5	18
Cobb	(0)	1	41
Others in Computer Lab	(1)	9	07
Math 385 (Wheeler)	(1)	3	09
Kalos	(0)	0	28
CSL	(1)	49	23
Civil Eng: Benesch	(0)	6	34
Civil Eng: Carlson	(0)	4	49
Civil Eng: Brooks	(0)	7	39
Civil Eng: Goodman	(0)	0	53
Civil Eng: Veletsos	(6)	17	47
Psychology: Twery	(0)	0	45
Psychology: Neuhaus	(0)	0	18
Psychology: Wrigley	(3)	4	06
Flaw and RAR	(1)	19	57
Leapfrog	(37)	117	43
Wasted	(1)	3	37
Operator Training	(0)	0	0
Demonstrations	(0)	7	54
Total:	61	Totals: 383	07

The number in the parenthesis is the numbers of errors associated with that work.

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[*] This figure appears smaller than a similar one called "repairs" in Table II because certain interruptions causing a delay in running of programs but not caused by a failure are included in "repairs" in Table II and included in Engineering time in Table I.

III ERROR FREQUENCY AND PERFORMANCE

The machine is normally used for "engineering" and maintenance between 8 AM and 12 N, and for a check of its performance between 4:30 PM and 5:00 PM of each weekday. Since the periods between 8 in the morning and noon, together with certain other irregular periods like Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more instructive from an error analysis standpoint to look at the periods between noon and midnight of each weekday in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind a summary table has been prepared using the period between noon and midnight of each weekday. This table lists the running time when the machine was operating properly, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 4:30-5:00 period (when the machine is checked) if no errors are found, the time is given to the "running OK" column. Each failure was considered to have terminated a running period and was followed by a repair period to be consistent in the method of preparing this table. Since the leapfrog code is very probably our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented as Table II.

DATE	RUNNING OK	REPAIRS	FAILURES DURING OK TIME	TYPE OF FAILURE CAUSING REPAIR TIME	WAS FAILURE FIXED ?	WASTED	LEAPFROG	FAILURES ON LEAPFROG	TYPE OF FAILURE
10-16	10:59	:57	1	Memory Chassis	Yes	:04	1:16	0	
10-17	11:35	:09	1	Comparison failure of leapfrog	No	:16	3:18	1	Comparison failure
10-20	11:53	0	0	None		:07	2:15	0	
10-21	10:31	1:17	1	Tape Reader	Yes(?)	:12	2:02	0	
10-22	11:48	0	1	Multiplication failure on leapfrog	No	:12	3:55	1	Multiplication failure
10-23	10:00	2:00	1	Tape Reader	Yes	0	3:13	0	
10-24	8:14	3:32	1	Flaw on #33 division test failure of leapfrog	Yes	:14	1:37	1	Flaw on #33 division test failure of leapfrog
10-27	9:09	2:42	3	Chad box got too full twice - sum check failure on LF	Yes Yes No	:09	2:39	1	Sum check failure on leapfrog not fixed
10-28	11:26	:28	4	1 division test 1 comparison test 1 tape check 1 comparison test	No No No No	:06	4:33	4	1 division test 1 comparison test 1 tape check 1 comparison test
10-29	10:40	:58	0	Work on punch		:22	3:05	0	
10-30	10:37	1:23	1	Multiplication error on leapfrog	Yes	0	1:17	1	Multiplication error (tube replaced)
10-31	11:14	:37	2	Neither identified	No No	:09	6:51	1	Division test failure
11-3	11:45	:12	1	Division test failure adj. #1 C.R. tube	Yes	:03	2:32	1	Division test failure adj. #1 C.R. Tube

DATE	RUNNING OK	REPAIRS	FAILURES DURING OK TIME	TYPE OF FAILURE CAUSING REPAIR TIME	WAS FAILURE FIXED ?	WASTED WASTED	LEAPFROG	FAILURES ON LEAPFROG	TYPE OF FAILURE
11-4	10:04	1:36	5	1 division test on LF 1 fuse blew in reader 3 unidentified in routine	No No No No No	:10	5:35	2	1 division test failure - 1 fuse in reader
11-5	9:33	2:17	3	680 volt power supply trans.failure; dirt in tape reader; bad phototube and C. F.	Yes Yes Yes	:10	2:56	1	Dirt in tape reader
11-6	11:50	:10	1	Division failure of LF	No	0	4:97	1	Division failure of LF
11-7	12:00	0	0	None		0	3:03	0	
11-10	11:16	:24	2	Comparison failure on LF due to flaw - Comparison test failure on LF	Yes No	:20	6:11	2	Comparison failure due to flaw - Comparison failure unlocated
11-11	10:27	1:23	2	Punch error Division test failure on LF	Yes Yes(?)	:10	5:10	1	Division test, intensity of No. 27
11-12	11:47	:10	1	Division test failure on leapfrog	No	:03	4:26	1	Division test failure
11-13	11:50	:10	2	Wrong random numbers on leapfrog and one unidentified error	No No	0	2:25	1	Wrong random numbers
11-14	11:32	:28	4	Dirt in reader; 680v supply fuse; reader light went out; flaw on No. 27	Yes Yes Yes Yes	0	1:31	1	Flaw on No. 27
TOTALS:	240:20	20:43	37			2:57	73:57	21	

It may be seen from this Table that the leapfrog operated on an average 3 hours and 30 minutes per error while overall for the month the machine ran about 6 hours and 30 minutes per error. The machine was in use about 240 hours and 20 minutes out of the available 264 hours or about 91% of the time. It may also be seen from the table that out of the 37 errors 18 were repaired and the other 19 remain "unrepaired".

The machine has operated a total of 1166 hours.

IV COMMENTS ON THE MACHINE

A. Memory

During the past month it has been necessary to change two of the cathode ray tubes in the machine. One of these was removed for its low read around ratio in the regular course of attempting to improve the overall read around ratio for the machine. The other tube was removed because of a poor connection to the aquadag which apparently developed during use. At the present time there are 10 available 3KP1 cathode ray tubes which can be considered as spare tubes for the machine. These have been checked to have fewer than 2 flaws each and to see that the read around performance is acceptable for at least 4 selected addresses.

The amplitudes of the signals associated with the memory have been measured. For a "standard" tube the amplitude of the dash pulse above the base line is 0.8 millivolt. The gain of the standard amplifier to a positive pulse is 75,000 giving a

signal (also positive) on the output of the amplifier for logical use of 60 volts (above the baseline). The sensing point of the logical circuit requires +10 volts, i.e., if the signal falls below the +10 volt mark for about 0.2 microsecond or more, then the output is registered as a dot and not a dash.

Some memory positions are operating with a 40 volt dash instead of the standard 60 volt dash. It is not known whether this is due to a change in tube characteristics or a change in amplifier gain. A change in the "intensity" setting of the cathode ray tube does not always increase the output signal.

B. Input-Output

Certain relatively minor changes have been made in the circuits so that it is possible to disconnect the punch chassis from the rest of the machine without incurring any damage. A new chad box has been built for the punch so that the machine can run for several hours between emptying of the chad box. A second input circuit has been added using the medium speed tape reader which was earlier used for a brief period on the ORDVAC. It operates at about 25 sexadecimal characters per second and will act as a standby in case there is any trouble with the high-speed tape reader (240 sexadecimal characters per second).

C. Test Routines

A consolidated engineering tape has been put together which contains a sequencing of tests for the machine. This was described in I.

On two occasions this month the leapfrog tape has been started and the routine proceeded in spite of the fact that a wrong set of random numbers was used. There is no independent check within the routine to see that the set of random numbers which is used at the very beginning is correct. This indicates that it would be desirable for us to somewhat alter the leapfrog routine in order to take this into account.

In addition the leapfrog routine does not lend itself readily to the actual location of an error once the routine has indicated an error. To that end a multiplication test routine has been written with the following characteristics:

1) A programmed multiplication which generates and stores all intermediate register contents

For each i from 1 to 38 (where i labels the step in the multiplication process):

2) The multiplication by the last i digits of the multiplier is executed and the product so obtained is corrected and checked against register contents after step i as obtained in 1).

3) Using the register contents after step i, the multiplication by the remaining 39-i multiplier digits is executed and the resulting product is corrected and checked against the original product.

4) The routine may be used in two ways:

   a) Multiplier and multiplicand are read from tape step 1) is executed, steps 2) and 3) are executed for each i. i is then reset to 1, and steps 2) and 3) are again executed for each i.

   b) The routine generates pseudo-random numbers then does 1) followed by 2) and 3) for every i, then generates new random multiplier and multiplicand and repeats 1), 2) and 3)

D. General

It has been recognized for some time that the addition process within the machine could be carried out in a shorter time if it were not necessary to shift the number to the right during the addition process and then make up for this by shifting the number back from right to left. This can be done if the extra set of gates already available in RI is used. A study is now being made of the necessary alterations to bring about the reduction in addition time.

V. RESEARCH AND DEVELOPMENT (This is supported in part by ONR Task 24)

A study of the logic and circuits for the inclusion of the drum with the machine is proceeding. A detailed system for this will be reported separately.

50 type 1698 and 20 type 1728 transistors have been received from Army sources. These are currently being checked for uniformity to serve as a measure of the tolerances required

if they are used in direct-coupled logical circuits.

The Williams apparatus currently designated as Williams X is now in operation. This makes it possible to test the read around ratio at each of the 1024 addresses of each of 6 separate cathode ray tubes simultaneously. IBM type cathode ray tubes have been tested for comparison purposes with 3KP1's. A separate report will be available on this comparison. A Radechon will be tried for digital storage in Williams II.

A study is being made in the theory of logical circuits. This has resulted in the following work.

1) Four theorems which permit the design of circuits when one is given metric relationships between the logical variables involved have been proved. These theorems are generalizations of those given in the seminar.

2) A matrix theory of transformations has been used to count the number of transformations in which variables are fixed.

3) A correspondence between logical variables and numerical vectors has been established and a general relationship between operations upon these vectors and the operations of Boolean algebra was derived.

4) A theorem was proved which shows that if the numerical vector corresponding to a given variable can be represented as a linear combination of other vectors with positive

coefficients then the given variable can always be represented as a branching diagram generated from the variables corresponding to the other vectors.

5) The Boolean algebra having 4 independent variables was studied by use of the machine. Normal vectors for the 65,536 variables in the system were generated and separated into classes which are basically different. Eight such classes were discovered and the number of variables in each class was recorded. A number of checks on these results were made.

Branching diagrams were formed for each class of variables by use of the methods mentioned in paragraph 1.

6) A closed subroutine was written to generate different types of input variables for systems containing from 1 to 5 independent variables. This subroutine, which will probably be used in connection with most codes connected with the study of logical circuits, has been thoroughly tested on the machine.

VI CONSTRUCTION

1. Finished WX except for painting some of the covers.
2. Machined 14 hinge strips for final computer cover.
3. Made covers for input-output covers for two 680 volt power supplies and covers for two 2000 volt power supplies. All of these covers need to be painted.

4. Started wiring of one 680 volt power supply; it cannot be finished until some transformers arrive.

5. Made 62 tape spools.

VII SEMINARS

The following seminars have been presented:

October 29, 1952
David Muller
Transformations of Systems of Logical Circuits I

November 5, 1952
David Muller
Transformation of Systems of Logical Circuits II

November 12, 1952
R. T. Gregory
A Routine for Computing Eigenvalues of a Symmetric Matrix

VIII PERSONNEL

The personnel associated with the group and hence the contributors to this report are:

Brown, Caroline
Butler, William
Clutterham, D. R.
Cobb, Bessie (1/2 time)
Gibson, Margaret
Gregory, R. T. (1/2 time)
House, Natalie R.
Huffman, William
Hughes, E. L.
Jones, Walter E.
Kerkering, T. E.
King, Richard (1/2 time)
Kudlich, R. A. (1/2 time)
Liu, R. C.
Leichner, G. H. (1/2 time)
Lopeman, H. E.
Meagher, R. E.
Michael, G. W.
Muller, David
Nash, J. P.
Newmark, N. M. (Exec. Committee)
Robertson, J. E.
Russell, Ramona
Shapin, Theodore
Taub, A. H. (1/2 time)
Wier, J. M.
Wheeler, D. J.

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R. E. Meagher

UNIVERSITY OF ILLINOIS

GRADUATE COLLEGE

DIGITAL COMPUTER

TECHNICAL PROGRESS REPORT

November 16, 1952 - December 15, 1952

I MATH GROUP ACTIVITY (This is supported in part by ONR Task 30)

A machine checked code which uses eigenvalue code 42 as a subroutine is now working. With this code experimental matrices can be generated and their eigenvalues and eigenvectors determined. By varying one parameter one can change the order of the matrix and by varying a second one can obtain different matrices of the same order. Similar codes will be written for eigenvalue codes 42A and 42B and then it will be possible to obtain a large amount of data for matrices of order 20 or less.

The refraction problem which was found to have spurious roots for weak shocks and nearly head on incidence when the two media were identical has been rectified to eliminate these roots. (These spurious roots did not occur for the normal refraction problem when the media were different). The tape itself, is now ready for the library but a detailed description will be deferred until the curved shock problem (a doctoral dissertation) has been run.

The curved shock problem is now in the machine testing stage. Included in it is a closed subroutine for finding real roots of an algebraic equation which may be used per se in the library. Here again the description will be deferred until the entire curved shock program is working.

A program was written and tested for determining the maximum errors in the solution of a set of simultaneous algebraic equations

due to unreliability of the coefficients.

A cube root program and a sine and cosine routine have been tested and are now being written up for the library.

A fully checked program for computing the digits of e was completed and the value of e was computed to 60,000 decimal places. An analysis of the digits is now being carried out.

A start was made on a program to test Goldbach's Hypothesis (which states that any even number is the sum of two odd prime numbers) up to a few million, but no results are yet available. The sieve method of generating prime numbers is working, however, and production of the primes needed to test Goldbach's Hypothesis can begin.

The following subroutines have been added to the program library during the past month.

61 Input one number, placing signed integer in R_1 and signed fraction in R_2.

62 Logical input variable. This program is designed to generate logical variables of various kinds.

63 Floating decimal arithmetic. This program replaces Code 46 which contained the FO order and may become obsolete.

64 Exponential. This program replaces NR_1 by exp (NR_1) if NR_1 is negative and by exp (NR_1 - 1) if NR_1 is not negative.

65 Standard subroutines. This program collects 5 frequently used subroutines (21, 23, 52, 53 and 61) together and arranges them with parameters for

easy use. It is intended primarily as an aid to persons wishing to check other programs.

II USE OF THE COMPUTER

Table I shows the distribution of machine time for the interval of November 16 through December 15, 1952.

TABLE I

Engineering time normally 9-12 AM and 4:30 - 5:00 PM		19h	20m
Engineering time at other times due to failure		18	17
Wheeler	(2)	49	18
Nash	(0)	3	45
Robertson	(0)	1	22
Leichner	(0)	2	51
Clutterham	(0)	16	46
King	(0)	1	14
Gregory	(0)	7	49
Cobb	(0)	1	13
Others in Group	(0)	2	33
Math 385	(0)	3	15
Math 384	(0)		36
Snyder - Physics	(0)	2	35
Kalos - Physics	(0)	4	51
CSL	(0)	18	51
Institute of Comm. Res. - Wilson	(0)		09
Civil Engineering - Benesch	(0)	12	15
Civil Engineering - Carlson	(0)	7	15
Civil Engineering - Veletsos	(0)	23	34
Civil Engineering - Brooks	(0)	12	15
Psychology - Neuhaus	(0)		19
Psychology - Wrigley	(0)	16	09
Math - Stat. Nicholson	(0)	1	29
Flaw and RAR	(0)	19	50
Leapfrog	(25)	89	28
Wasted	(0)	3	53
Demonstrations	(0)	2	31
Totals:	(27)	343	43

The number in the parenthesis is the number of errors associated with that work.

The following list gives the problem specifications for new codes which were tried during the month. It does not indicate how the machine was used because problems with numbers less than 35 may have consumed large amounts of machine time.

NUMBER	PROBLEM SPECIFICATION	AFFILIATION
35	Compute sequence of primes	Computer
36	Factor leadings, 30 x 30 matrix	Psychology
37	Extract 7 factors from correlation matrix	Psychology
38	Find beam deflection at 1/12 points under various dynamic moments	Civil Engr.
39	Compute a force function to be used in a code for the dynamic response of a closed ring	Civil Engr.
40	Print successive odd numbers and give smallest factor if not prime	Computer
41	Check cube root routine	Computer
42	Solve for true field vs ideal field in various coils	Physics (Snyder)
43	Check sin x, cos x	Computer
44	Check exp x	Computer
45	Solve 9 non-linear second order partial differential equations with variable coefficients	Civil Engr.
46	Check sin x, cos x	Computer
47	Test standard subroutine code	Computer
48	Convert tape punched from IBM cards to form usable by ILLIAC	Psychology

NUMBER	PROBLEM SPECIFICATION	AFFILIATION
49	Eigenvalues and eigenvectors of 30 x 30 matrix	Psychology
50	**Laplace equation for simple boundary**	**Elec. Engr.**
51	Shock wave problem	Computer
52	Incomplete Beta function code checker	Math Statistics
53	Logical quantities to aid in circuit simplification	Computer
54	Incomplete Beta function code checker	Math Statistics
55	Calculate correlation coefficients for dichotomous data	Psychology
56	Experimental eigenvalue program	Computer
57	Eigenvalues and eigenvectors of [illegible] x [illegible] matrix	Psychology
58	Frequencies, $(\text{chi})^2$, digrams and poker hands for 5000 decimal digits of e	Computer
59	Produce prime differences in range 0-50,000	Computer
60	Factor loadings, 21 x 21 matrix	Psychology
61	Check errors in simultaneous algebraic eq.	Computer
62	Form prime differences from 0 to 1 or 2 million	Computer
63	Factor loadings of 17 x 17 matrix	Psychology
64	Neville's interpolation scheme	Physics

NUMBER	PROBLEM SPECIFICATION	AFFILIATION
65	Principal axes factor analysis, 15 x 15 matrix	Psychology
66	Compute sine integrals and sines	Computer
67	Test 1.8 precision routine	Computer
68	Read in matrix and punch out transpose	Psychology

III ERROR FREQUENCY AND PERFORMANCE

The machine normally used for "engineering" and maintenance between 8 AM and 12 N, and for a check of its performance between 4:30 PM and 5:00 PM of each weekday. Since the periods between 8 in the morning and noon, together with certain other irregular periods like Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more instructive from an error analysis standpoint to look at the periods between noon and midnight of each weekday in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind a summary table has been prepared using the period between noon and midnight of each weekday. This table lists the running time when the machine was operating properly, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 4:30-5:00 period (when the machine is checked) if no errors are found, the time is given to the "running O.K." column.

DATE	RUNNING OK	REPAIRS	FAILURES DURING OK TIME	TYPE OF FAILURE CAUSING REPAIR TIME	WAS FAILURE FIXED?	WASTED	LEAPFROG	FAILURES OF LEAPFROG	TYPE OF FAILURE
11/17	12:00	0	0			0	1:56	0	
11/18	9:25	2:35	2	1 - Div. test-adder tube 1 - sum check	yes no	0	2:42	2	1 - Div. test-adder tube 1 - sum check
11/19	11:58	0	0			:02	2:48	0	
11/20	11:41	:19	1	1 - comp. test-adj. sev. mem. tubes	yes	0	4:22	1	1 - comp. test-adj. sev. mem tubes
11/21	3:39	8:21	1	Install new adr. gen. power supply 1 div. test failure	no	0	:59	1	1 - div. test
11/24	10:12	1:44	6	1 - Flaw pos #7 1 - Bad printer line relay 2 - Flaws #37 1 - comp. test 1 - not printing corr.	yes yes no yes no no	:04	1:31	3	1 - comp. test 1 - not printing corr. 1 - div. test Flaw #37
11/25	11:06	:52	2	Tighten terminals on in-out rack Light in reader went off	yes yes	:02	1:14	0	
11/26	11:57	0	0			:03	2:20	0	
11/28	12:00	0	0			0	1:23	0	
12/1	11:45	:13	2	2 - Comp. test	no no	:02	4:04	2	2 - comp. test
12/2	11:58	0	1	1 - not identified	no	:02	4:33	0	
12/3	11:55	0	0			:05	4:14	0	

DATE	RUNNING OK	REPAIRS	FAILURES DURING OK TIME	TYPE OF FAILURE CAUSING REPAIR TIME	WAS FAILURE FIXED?	WASTED	LEAPFROG	FAILURES OF LEAPFROG	TYPE OF FAILURE
12/4	12:00	0	0			0	3:05	0	
12/5	10:33	1:27	1	1 - +300v. fuse blew	no	0	2:44	1	1 - +300v. fuse blew
12/8	11:44	:09	2	1 - not identified 1 - mult. test, adj. #10	no yes	:07	4:10	1	1 - mult. test, adj. #10
12/9	12:00	0	0			0	1:42	0	
12/10	12:00	0	0			0	1:19	0	
12/11	11:50	:10	1	1 - not identified	no	0	1:59	1	1 - not identified
12/12	10:37	1:23	1	1 - possible R_3 button	no	0	3:53	0	
12/15	11:16	:44	1	1 - reader light out	yes	0	5:46	0	1 - tape check, tape unevenly punched, not counted as an error
TOTALS:	221:36	17:57	21		9 yes 12 no	:27	56:44	12	

Each failure was considered to have terminated a running period and was followed by a repair period to be consistent in the method of preparing this table. Since the leapfrog code is very probably our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented as Table II. It may be seen from this Table that the leapfrog operated about four hours per error. Overall the machine operated about ten hours per error. Several errors produced by dirt on the tapes are not considered to be machine errors. The machine was operative about 92 percent of the time it was scheduled to be in operation.

IV COMMENTS ON THE MACHINE

A. Memory

Three cathode ray tubes were changed in the machine during the month. One change was made because of flaws and two of the tubes were changed because the second anode connection to the aquadag failed. No memory chassis were replaced or repaired. A new power supply was installed in the address generator of the memory for the purpose of providing a more highly regulated negative voltage for the address generator. This power supply caused the read around performance of the machine to be perceptibly poorer for several days because voltages produced by the power

supply were slightly different from the previous power supply. This provides clear evidence that there is a change in the read around characteristics of the cathode ray tubes if for any reason the raster position is changed. The cause of the effect is not known. Two sample tubes with the type number C-73376A have been received from RCA for memory use. Both of these tubes are substantially free of flaws and one of them has a read around ratio of about 350 and the other 500 under the same conditions that the read around performance of our 3KP1's is about 40.

100 3KP1 tubes have been received which, when tested, can be used a replacements. The C-73376A tube is not yet available in more than sample quantities.

B. Input-Output

Because of the pressing need for extra printing facilities the printer supplied by CSL has been converted so that our standard sexadecimal characters may be printed using our code. In addition most of the other characters in the machine have been left unaltered so that by the use of the special print orders it is possible to print most of the letters of the alphabet from codes obtained from the machine.

C. General

A number of logical adder circuits have been investigated and considered in the last two years. A logical adder based upon a

circuit proposed by the Swedish Computer Group at Stockholm appears to be better than any of the others yet proposed. The circuit provides a carry time of less than 2 1/2 microseconds for 40 stages and an addition time within any one stage of about 5 microseconds for the slowest transition. Eight tubes per stage are required for this adder. Since the use of this adder would eliminate the need for the 680 volt power supply, would reduce the total number of tubes within the machine, and would cut the setting of the carry delay circuit from 16 microseconds to about 9 microseconds it would appear to be a worthwhile change in the machine.

V RESEARCH AND DEVELOPMENT (This is supported in part by ONR Task 24)

The logical arrangement for the inclusion of the drum as an auxiliary memory with the machine has been decided upon and the effort is currently being placed on the design of the circuits for this arrangement. No significant change in the system has been made since the last report on it.

Photographs have been taken of the collector characteristics for the type 1768 transistors and for part of the type 1698 transistors which have been received. These have been obtained so that a tolerance study can be made of the characteristics presently available in the transistors for use in direct-coupled circuits.

The theory of logical design and methods for its application have been developed in several directions. These are:

1. A normal expansion for logical functions has been formed which has some unusual metric properties. A study of these properties is still in progress.

2. The theory of this expansion has been used to generalize a number of previous results.

3. A generalization of this normal expansion has been applied to the theory of error detection and correction and systematic methods for constructing error detecting codes have been developed in this way.

4. Application of this same theory to the simplification of circuits have been successful and a number of circuits have been a simplified as far or farther than was possible by conventional methods.

5. A code has been written to allow the machine to carry out the algebraic work involved in forming the expansion described here.

VI CONSTRUCTION

1. +680 volt power supply completed
2. -2000 volt power supply completed except for one 8020 socket
3. Covers for -2000 volt supply painted
4. Changed DC switch on computer
5. Changed power panel on Add. Gen.
6. Sealed leaks in air conditioner
7. One six stage logical adder completed
8. Enough parts made to construct 25 full 6 gang bay three dim. chassis
9. 7 double transistor sockets made

VII SEMINARS

November 18, 1952
Proposed Changes to Speed up Additions
James E. Robertson

VIII PERSONNEL

The personnel associated with the group and hence the contributors to this report are:

Brown, Caroline
Butler, William
Clutterham, D. R.
Cobb, Bessie (1/2 time)
Gibson, Margaret
Gregory, R. T. (1/2 time)
House, Natalie R.
Huffman, W. L.
Hughes, E. L. (Term. 12/1)
Jones, W. E.
Jarrett, T.
Kerkering, T. E.
King, Richard (1/2 time)
Kudlich, R. A. (1/2 time)

Liu, R. C. (Term. 12/15)
Leichner, G H. (1/2 time)
Lopeman, H. E.
Meagher, R. E.
Michael, G. W.
Muller, David
Nash, J. P.
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Robertson, J. E.
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Wheeler, D. J.

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REM/nrh

UNIVERSITY OF ILLINOIS

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TECHNICAL PROGRESS REPORT

December 16, 1952-January 15, 1953

I MATH GROUP ACTIVITY (This is supported in part by ONR Task 30)

A significant gap in the library will be filled when a double precision routine is coded. Two such routines are now nearly complete. Both are interpretive routines, one being fixed point and the other floating point.

A program for the solution of the two-dimensional Laplace equation for an arbitrary boundary has been tried successfully with two examples.

Data about time, number of transformations for convergence and $\sum r_i^2$ where the r_i are residuals have been obtained for seven matrices of orders 4, 8, 12 and 16 using the eigenvalue codes described in a previous report. When these data are obtained for seven matrices of order 20, a table displaying the results will be constructed.

The above mentioned matrices were generated by the ILLIAC and apparently all were well-conditioned. A study will also be made of matrices with close eigenvalues and equal eigenvalues.

The curved shock problem contained a logical error which necessitated rewriting part of the code.

During the past month the following new programs have been added to the library:

66. Sine-cosine. Using NR_1 as x this routine places
(sin x)/2 in storage location 1
(cos x)/2 in storage location 2
(sin 2x)/2 in storage location 0 and in R_2
(cos 2x)/2 in R_1.

67. Neville's interpolation method. This routine interpolates to an arbitrary depth in one or more tables which are stored in the machine.

68. Cube root. This routine replaces $x = \mathrm{MR}_1$ by $\sqrt[3]{x}$.

69. Address search II. This routine locates and prints all words with given address n.

70. Control transfer check. This routine prints a list of the last n control transfer orders executed by a program.

71. Inverse interpolation. This routine will find a real root of $f(x) = 0$.

Contributions to the library are now being made by programmers outside of the Computer Laboratory. The two interpolation routines (67 and 71) were written by a member of the Physics Department (Snyder).

In addition to the computer staff there are now 22 people in 9 departments of the University actively engaged in preparing programs for the computer.

The following list gives problem specifications for new codes which were tried during the month. It does not indicate how the machine was used because problems with numbers less than 69 may have consumed large amounts of machine time.

NUMBER	PROBLEM SPECIFICATION	AFFILIATION
69	Log summation to analyze operations	Computer
70	Matrix assembly code	Psychology
71	Test sine-cosine routine	Computer

NUMBER	PROBLEM SPECIFICATION	AFFILIATION
72	Solve 5 simultaneous linear algebraic equations	Physics
73	Machine test problem (Carpet)	Computer
74	Compute similarity measure between response patterns in public opinion studies	Inst. Comm. Res.
75	Preliminary study of Helium Wave Eq.	Physics
76	Electron cyclotron trajectories from relativistic differential equations of motion	Electrical Engineering
77	Metric relations in a 32 state Boolean algebra system	Computer
78	Multiply 2 30 x 30 matrices	Psychology
79	Scale computation for amplifier design nomograph	Computer
80	Coefficients to fit random walk data by least squares	Computer
81	Find how many of each decimal digit are on a tape	Computer
82	Given a symmetric matrix (a_{ij}) to form the matrix $(a_{ij}/\sqrt{a_{ii}\ a_{jj}})$.	Psychology
83	Calculate transition probability integrals using shielded hydrogen wave functions	Physics
84	Generate wave forms	Computer
85	2-dimensional Laplace equation	Computer
86	Compute sums of squares of rows and columns of a matrix	Psychology
87	Address search routine	Computer

NUMBER	PROBLEM SPECIFICATION	AFFILIATION
88	Field distribution in a thick solenoid	Physics
89	Sorting comparison	Computer
90	Set of ordinary differential equations for 32 sets of initial conditions	Math
91	Thermocouple problem	Chem. Eng.
92	Solve 22 sets of linear simultaneous algebraic equations	Chemistry
93	Checking routine for control transfer	Computer
94	Calculate a real root of $f(x) = 0$	Physics
95	Double precision arithmetic	Computer
96	Improved solution of simultaneous linear algebraic equations by using residuals	Computer
97	Solve $(\sum_{1}^{8} a_i \cos x_i)/\sum_{1}^{5} b_k \cos x_k$ for many points	Electrical Engineering
98	Compute arctangents using floating decimal representation	Computer
99	Solve 7 simultaneous linear algebraic equations	Math
100	New leapfrog	Computer

II USE OF THE COMPUTER

Table I shows the distribution of machine time for the interval of December 16, 1952 through January 15, 1953.

TABLE I

Engineering time normally 9-12 AM and 4:30-5 PM	25h	20m
Engineering time at other times due to failures	30	13
Wheeler	4	52
Nash	3	16
Leichner	1	49
Clutterham	13	49
King	3	05
Gregory	13	57
Cobb		40
Muller	5	42
Others in Computer Group	1	17
Classes	2	42
Physics	19	39
C. S. L.	20	32
Civil Engineering	15	37
Psychology	16	20
Electrical Engineering	4	52
Institute of Comm. Res.		18
Math Statistics	1	13
Chemistry		29
Chem. Engr.	1	09
Mathematics	1	17
Wasted	1	42
RAR and Flaw Test	22	41
Leapfrog	95	38
Demonstrations	2	41
Total	310	50

III ERROR FREQUENCY AND PERFORMANCE

The machine is normally used for "engineering" and maintenance between 8 AM and 12 N, and for a check of its performance between 4:30 PM and 5:00 PM of each weekday. Since the periods between 8 in the morning and noon, together with certain other irregular periods like Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more instructive

from an error analysis standpoint to look at the periods between noon and midnight of each weekday in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind a summary table has been prepared using the period between noon and midnight of each weekday. This table lists the running time when the machine was operating properly, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 4:30-5:00 period (when the machine is checked) if no errors are found, the time is given to the "running O. K." column. Each failure was considered to have terminated a running period and was followed by a repair period to be consistent in the method of preparing this Table. Since the leapfrog code is very probably our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented as Table II. (Continued next page)

DATE	RUNNING OK	REPAIRS	DURING OK TIME	TYPE OF FAILURE CAUSING REPAIR TIME	FAILURE FIXED?	WASTED	LEAPFROG	OF LEAPFROG
12/16	10:19	1:41	6	1 - hang-up - 3 gate tubes in Printer Con. 1 - Comparison 1 - Printer 1 - Printer 1 - Comparison 1 - Comparison	Yes No No Yes No Yes	0	3:05	3
12/17	10:50	1:10	1	1 - Printer - shorted tube	Yes	0	3:10	1
12/18	10:34	1:23	2	1 - Comparison test flaw 1 - Printer	Yes Yes	3	2:53	1
12/19	10:37	:49	3	1 - Comparison test flaw 1 - Fuse blew +300 1 - Division test	Yes No No	34	2:24	3
12/22	11:46	:10	1	1 - Sum Check	Yes	4	6:16	1
12/23	11:29	:29	1	1 - Tape Check	No	2	3:13	1
12/26	9:07	:08	0			0	6:29	0
12/29	10:27	1:33	2	1 - Tape reader not stopping 1 - Division test	Yes No	0	5:10	1
12/30	9:41	2:19	4	1 - Not identified 1 - Mult. test 1 - Comp. test 1 - Not identified	No No No No	0	5:06	3
1/2/53	12:00	0	0			0	5:40	0
1/5/53	11:00	1:00	0			0	1:18	0

(Continued on next page)

DATE	RUNNING OK	REPAIRS	DURING OK TIME	TYPE OF FAILURE CAUSING REPAIR TIME	FAILURE FIXED?	WASTED	LEAPFROG	FAILURES LEAPFROG
1/6/53	9:15	2:43	0			:02	:22	0
1/7/53	0	0	1	1 - 680 volt power supply failed	*	0	0	0
1/8/53	0	0	0			0	0	0
1/9/53	6:45	0	0			0	7:44	0
1/12/53	11:25	:31	1	1 - Punch not stopping	Yes	:04	2:52	0
1/13/53	11:49	:06	0			:05	2:12	0
1/14/53	11:28	:28	0			:04	1:22	0
1/15/53	11:55	:01	0			:04	1:14	0
Totals	179:27	14:31	22			1:02	65:30	14

* Adder Installed

It may be seen from this Table that the leapfrog operated about 4 2/3 hours per error. Overall the machine operated about 9 hours per error.

On January 7 at 8:42 AM the +680 volt power supply failed. It had been planned to install the logical adder starting January 8. Since the +680 volt power supply is not used with the new adder it was decided to install it one day earlier than planned - so that the +680 volt power supply would not need to be repaired. This was done and the table lists one error because of this failure but no repair time is listed. The machine was put back into use at 5:15 PM January 9. Except for this irregularity the table is prepared just as in previous reports.

IV COMMENTS ON THE MACHINE

A. Memory

Four cathode ray tubes were changed in the machine during the month. Two of these were changed for poor read around ratio since a new supply of 3KP1 tubes has been received. One tube was changed because of focusing difficulties and the fourth was changed because of a bad aquadag connection.

One-hundred 3KP1 cathode ray tubes have been received on a recent order. Approximately fifty of these tubes have read around ratios in excess of forty according to our standard tests but some of these fifty may have flaws which will make them unsuitable for

use in the machine. The read around ratio in the machine at the present time is such that there is usually one print-out at a read around of forty after two tests.

Our present read around tests are made with the memory cleared to dots in that half of the tube in which the read around test is being carried out. If the memory is cleared to dashes instead of dots then the number of print-outs is about three at thirty and eighteen at forty. It is therefore clear that our read around test should be altered to consider this more unfavorable case.

B. New Adder

On Wednesday, January 7, 1953 the new logical adder mentioned in the last report was installed in the machine. The carry propagate time in this adder was measured in the machine to be two microseconds and the carry collapse time was measured to be three microseconds. These times may be compared with carry times of about 9 1/2 microseconds for the older adder. It has therefore been possible to reduce the time allowed for a carry in the execution of any order requiring addition. This has affected the speed of the machine on multiplication and division orders but not on addition orders. The addition orders still require four regeneration periods and hence there is no reduction in the operation times for the addition orders. Table III shows the

present operation times for multiplication and division, as well as the times with the older adder.

TABLE III

	OLD ADDER	NEW ADDER
Multiply		
Multiplier all zeros	668 μsec	640 μsec
Multiplier all ones	1148 μsec	820 μsec
Division	1148 μsec	780 μsec

Since the regeneration period is now about 21.4 μseconds as compared to the previously reported figure of 22.4 μseconds, the multiplication time with all zeros (not affected by the new adder) is slightly shorter than reported earlier. The multiplication with all ones and the division times are perceptively different because the left and right shift times are somewhat different. Except for inaccuracies the operation times should be an integral multiple of 21.4 microseconds.

C. General

The introduction of the new adder has eliminated the need for a 680 power volt supply. After the introduction of the new adder a test was made of the allowable values of each of the four main power supplies to ascertain where a failure would occur. Table IV shows in the first column the nominal value of the power supply voltage, in the second column the highest absolute value of the corresponding voltage which does not cause trouble in the

machine and in the third column the lowest value of the absolute voltage which does not cause an error or "hang-up" in the machine. The remark associated with each tolerance limit indicates the type of fault which occurs. The test was carried out using the crippled leapfrog routine.

TABLE IV

+300V	+322V (Error)	+271V (Hang-up)
+150V	+166V (Hang-up)	+142V (Error)
+100V	+108V (Hang-up)	+94V (Hang-up)
-300V	-325V (Hang-up)	-280V (Hang-up)

At the present time each of the main line voltages is being checked to ascertain that no excursion greater than 5% of the value of the line voltage takes place during the operation of the machine. The new adder was installed after the machine was in use 1707 hours according to its running meter. The machine has been used about 1802 hours when this report is written. The new adder reduces the number of tubes in the machine from 2079 to 2774.

V RESEARCH AND DEVELOPMENT

A report is being prepared on the study of logical circuits.

A study is being made of the arithmetic control and certain simplifications that could be made in it, perhaps to be carried out at the same time that the orange gate is added.

Work on the drum circuits is continuing.

Some considerable time has been spent investigating certain anomalies in the static collector characteristics of some type 1768 transistors. These anomalies indicate the presence of negative resistance regions in both the high and the low current portions of the curves. Some direct-coupled logical circuits have been considered using these transistors and these are being studied.

A new leapfrog routine has been written and partially tested.

VI CONSTRUCTION

1. Added neon indicator on C.R.T. filament potential.
2. Logical adder built and installed in computer.
3. Repaired printer circuit.
4. Painted and installed input-output covers.
5. Repaired punch.
6. Repaired catch on Ferranti tape reader.
7. Built amplifier and logical circuit for core memory.
10. Built driver for core memory.
11. Some work on final covers.

VII SEMINARS

December 17, 1952
A Logical Adder
Joseph M. Wier

January 14, 1953
Metric Properties of Boolean Algebra
David E. Muller

VIII PERSONNEL

The personnel associated with the group and hence the contributors to this report are:

Brown, Caroline
Butler, William
Clutterham, D. R.
Cobb, Bessie (1/2 time)
Gibson, Margaret
Gregory, R.T. (1/2 time)
House, Natalie R.
Huffman, W. L.
Jones, W. E.
Jarrett, T.
Kerkering, T. E.
King, Richard (1/2 time)
Kudlich, R. A. (1/2 time)

Leichner, G. H. (1/2 time)
Lopeman, H. E.
Meagher, R. E.
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UNIVERSITY OF ILLINOIS

GRADUATE COLLEGE

DIGITAL COMPUTER

TECHNICAL PROGRESS REPORT

January 16, 1953 - February 15, 1953

I MATH GROUP ACTIVITY (This is supported in part by ONR Task 30)

The computation of matrix data mentioned in the last report has been completed. Data on time of calculation, number of transformations, and sum of squares of residuals have been obtained. A report of the results is now being prepared for publication.

Estimated computing time remaining to finish the curved shock problem is 80 hours. One set of the families of curves had several infinities in it and the analysis required a diminished mesh size in the auxiliary subroutine.

A program for computing residuals in the solution of simultaneous linear algebraic equations has been written. With this program it is possible to increase the accuracy of solutions which have already been obtained with standard library codes 47 or 51.

Studies have begun on the problem of accelerating the convergence of solutions of partial differential equations.

Four chapters of an internal report on metric properties of Boolean algebra and their applications to switching circuits have been completed. This report will contain results which will soon be submitted for publication.

NEW LEAPFROG

A new leapfrog test program, Leapfrog II, is now being used. Leapfrog II tests the machine more thoroughly than Leapfrog I did and upon failure provides information which makes fault-finding easier than it was with the old program.

The program contains three main tests: multiplication, division and comparison. The comparison test is used to check the results of other minor tests. These other tests are input-output, carry propagate, left shift, logical product, right shift with all ones, right shift with all zeros, and an extra input-output test which is performed every 128 jumps (a minor cycle).

Five copies of the routine are carried in the memory. The working copy is copy 3, which contains the orders actually being obeyed. The routine has to transfer 128 words in order to leap, and the multiplication and division tests are each performed once for each word that is transferred. The working copy takes one word from copy 2 and translates it into words suitable for copy 1 and copy 5. The word for copy 1 is placed in position and the other translated word is compared with the corresponding word of copy 5. If it disagrees the comparison test fails and the machine stops. There are then printed out the corresponding words for copies 2, 3, 4 and 5 together with their locations in the memory. This is followed by the addresses of the first word of the working copy and of the word being transferred and then the word from copy 2 translated into copies 1 and 5. Finally the difference between the two versions of copy 5 is printed.

If the multiplication or division tests fail, the machine stops and then a set of 18 numbers giving pertinent data is printed.

When no failures occur, after 128 words have been transferred from copy 2 to copy 1 a leap occurs and the old copy 2 now becomes the working copy. After about 20 minutes of operation every word of the working copy has occupied every position of the memory.

As the program is running the input and output are checked by reading back the punched output tape.

During the past month the following new programs have been added to the library.

72. A search for the real roots of $f(x)=0$

73. Leapfrog II

74. Improved solution of simultaneous linear algebraic equations by use of residuals

75. Parameter-set print. This program will print the contents of R_1 as a decimal or fraction, with or without sign, to $n \leq 11$ decimal places.

Program 72 was written by Professor J. N. Synder of the Physics Department.

The following list gives problem specifications for new codes which were tried during the month. It does not indicate how the machine was used because problems with numbers less than 101 may have consumed large amounts of machine time.

NUMBER	PROBLEM SPECIFICATION	AFFILIATION
101	Calculation of covariance	Psychology
102	Calculation of trigonometric tables at intervals of $\pi/20,000$	Electrical Engineering
103	Solution of simultaneous linear algebraic equations	Math
104	Leapfrog post mortem	Computer
105	Test print routine	Computer
106	Feedback amplifier design	Computer
107	Acoustic lens design	Electrical Engineering

NUMBER	PROBLEM SPECIFICATION	AFFILIATION
108	Matrix column sums	Psychology
109	Meson-nucleon cross sections	Physics
110	Symmetric to triangular matrix	Psychology
111	Nim	Physics

Dr. C. F. Wrigley of the Psychology Department has supplied the following list of machine-tested programs which were written and are being used by the Psychology Department. It is expected that many of these will be incorporated into the Computer library.

1. Principal axes factor loadings (A development of Illinois Code 42)
2. Reduction of a matrix to triangular form - i.e., square root factor analysis
3. Correlations between dichotomous variables - i.e., phi coefficients
4. Covariances between dichotomous variates
5. Conversion of a product matrix to standard form - i.e., conversion of covariances to correlations
6. Matrix multiplication
7. Sums of squares of rows and columns of a matrix
8. Transposition of a matrix
9. Scaling of IBM Type 63 tapes.

II USE OF THE COMPUTER

Table 1 shows the distribution of machine time for the interval January 16 through February 15, 1953:

TABLE I

	TIME
Engineering Time 8-12	27:20
Engineering Time at other times	23:04
Computer Group	
Wheeler	4:17
Leichner	5:09
Clutterham	94:50
King	3:39
Gregory	5:41
Cobb	2:15
Muller	:40
Class Students	5:44
Department	
Physics	12:32
CSL	21:16
Civil Engineering	6:28
Psychology	25:52
Electrical Engineering	16:04
Inst. Comm. Res.	:31
Chemical Engineering	3:09
Mathematics	:53
Physical Education	:11
Demonstrations	1:16
Wasted	3:19
RAR	23:59
Leapfrog	80:10
Total Hours in Use	368:19

III ERROR FREQUENCY AND PERFORMANCE

The machine is normally used for "engineering" and maintenance between 8 AM and 12 M, and for a check of its performance between 4:30 PM and 5:00 PM of each weekday. Since the periods between 8 in the morning and noon, together with certain other irregular periods like Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more

instructive from an error analysis standpoint to look at the periods between noon and midnight of each weekday in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind a summary table has been prepared using the period between noon and midnight of each weekday. This table lists the running time when the machine was operating properly, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 4:30-5:00 period (when the machine is checked) if no errors are found, the time is given to the "running O. K." column. Each failure was considered to have terminated a running period and was followed by a repair period to be consistent in the method of preparing this Table. Since the leapfrog code is very probably our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented as Table II.

DATE	RUNNING OK	REPAIRS	FAILURES DURING OK TIME	TYPE OF FAILURE CAUSING REPAIR TIME	WAS FAILURE FIXED?	WASTED	LEAPFROG	FAILURES OF LEAPFROG
1/16/53	11:43	17	1	Extra dash 2^{-8}	Yes	0	1:07	0
			1	Fuse blew	No			
1/19/53	8:27	3:28	1	Not identified	No	:05	:28	0
1/20/53	12:00	0	0			0	3:22	
1/21/53	10:57	:54	0			:09	:43	
1/22/53	11:34	:10	0			:16	1:08	
1/23/53	11:56	0	0			:04	:17	
1/26/53	12:00	0	0			0	2:19	
1/27/53	11:25	:35	1	Division test - extra dash 2^{-31}	Yes	0	2:07	1
1/28/53	10:35	1:25	1	Not identified	No	0	4:29	1
			1	Flaw 2^{-37}	Yes			1
			1	Associated with input	No			
			1	Not identified	No			
1/29/53	10:41	1:19	1	Associated with input	No	0	1:05	1
			1	Carry test failure	No			1
			1	Flaw 2^{-35}	Yes			1
1/30/53	6:53	5:07	1	Associated with reader	No	0	2:24	
			2	Not identified	No, No			2
			1	Associated with reader	No			
2/2/53	10:54	1:04	1	Contact broke on printer relay	Yes	:02	4:42	
			2	Not definitely established	No			2
				Adjusted $2^{-4} + 2^{-29}$ in mem.	No			
2/3/53	11:40	:19	1	Dirt in reader	Yes	:01	2:45	
			2	Dirt on Tape (both on read-in of code)	Yes (?) Yes (?)			2
			1	Dirt in reader	Yes			1

DATE	RUNNING OK	REPAIRS	DURING OK TIME	TYPE OF FAILURE CAUSING REPAIR TIME	WAS FAILURE FIXED?	WASTED	LEAPFROG	FAILURE OF LEAPFROG
2/4/53	10:13	1:47	1	Comparison test	No	0	2:14	1
			2	Intermittent reader light	No			2
					Yes			
2/5/53	11:19	:41	1	Associated with punch	No	0	1:24	
			2	Printer-not further ident.	No			
					No			
2/6/53	6:50	4:48	1	Read 0 for L	No	:22	2:09	1
			4	Not identified	No			4
			2	Punch-not punching space hole	No			2
			1	Reader-assoc. with A.C. voltage setting	No			
			1	Comparison test - in-out test	No			1
			1	Printer control	No			
2/9/53	4:43	7:17	1	Punch-Osc. in in-out control	Yes	0	:30	1
2/10/53	11:58	0	0			:02	:43	0
2/11/53	11:21	:34	1	Low intensity 2^{-8}	Yes	:05	1:27	1
2/12/53	11:33	:25	1	Low voltage on reader light	Yes	:02	1:16	1
2/13/53	12:00	0	0			0	1:41	0
				(Most of the sources of input and output errors have been corrected since the period covered by this table)				
	220:42	30:10	41		13 yes 28 No	1:08	37:53	24

IV COMMENTS ON MACHINE

A. Memory

Five 3KP1 cathode ray tubes were replaced during the month. Four of these were replaced in order to improve the RAR and one was replaced because of a flaw. No memory chassis was replaced or repaired during the month.

From the group of 100 3KP1's that were received about six weeks ago 19 tubes have read-around ratios in excess of 48 and are free from flaws.

Changes in memory synchronization and memory control have made it possible to reduce the memory period from 22 μseconds to 18 μseconds.

B. New Adder

Since the new logical adder was installed and put into service there have been no failures which could be attributed to the adder circuit.

C. Input-Output

During the month a considerable amount of difficulty and a number of failures were due to the input and output parts of the machine. This can be seen by inspection of Table II. In fact, 23 out of the 41 errors were associated with input-output. Some failures in the punch were due to the fact that some of the parts were vibrated until they were loose. In addition to this some errors occurred because the cathode followers providing information for the output circuits were found to have RF oscillations. One of the failures with the output was due to a shorted tube in the decoding chassis associated with input or output and operate. Failures in the Ferranti tape reader were found to be due to slots cut in the guide pins by the tape since the reader was put into operation.

D. Test of Tubes

A sample of 48 tubes was removed from the RII register in order to check on their condition. It was found that a number of the tubes had some leakage current between the filaments and cathode and in some cases between grids and filaments. No shorts or other difficulties were found which would indicate that an error might be caused by the tubes or that a wholesale tube replacement program should be started. The machine has been operated about 2154 hours.

V RESEARCH AND DEVELOPMENT (Supported in part by ONR Task 24)

The design of many of the circuits for the drum memory has been completed. The circuits associated with the drum memory and their drawing numbers are shown in Table III.

DRUM CIRCUITS

DRAWING NO.	TITLE	CIRCUIT DUPLICATED N TIMES	TUBES/CIRCUIT	TOTALS
Not drawn	Preamplifier and Recording Tube	200	4	800
M-475	Matrix amplifier	50	1	50
M-475	Record amplifier	8	6	48
S-368	Pulser	6	6	36
Not drawn	Playback amplifier	4	12	48
Not drawn	Control track amplifier	4	14	56
M-453) M-454)	Secondary matrix	2	50	100
M-471	Primary matrix	1	27	27
M-474	Record gating chassis	1	36	36
M-477	Playback gating chassis	1	32	32
M-478	Gating control	1	27	27
M-353	Word counter	1	36	36
M-472	Coincidence	1	27	27
M-476	Clear driver and origin synchronization	1	26	26
M-480	Odd voltage supplies	1	3	3
M-479	D.C. turn on and safety	1	0	0
			Total:	1352

A new high speed comparator for paper tapes has been put into use. It uses two Western Union tape readers and operates at about 20 sexadecimal characters per second. A new "medium speed" tape reader for the computer is being designed and tested. This is intended to act as a substitute during periods when the Ferranti tape reader is being serviced.

VI CONSTRUCTION

1. One tape comparator unit
2. Eight pulsers for core memory
3. Tape spool for transmitter distributor
4. Model drum playback amplifier and record tube
5. Model of drum playback output amplifier
6. Word counter for drum memory
7. Secondary matrix (M-453) for drum memory
8. Secondary matrix (M-454) for drum memory
9. Two pulser chassis (six pulses) for drum memory
10. Window frames for final computer covers partly finished
11. Pawl and guide plate for new output punch
12. Model of Eddy current clutch as take-up unit for tapes.

VII SEMINARS

January 21, 1953
HIGH DENSITY MAGNETIC RECORDING
Theodore Shapin Jr.

January 28, 1953
Proposed Arithmetic Control Changes
James E. Robertson

February 11, 1953
RECENT DEVELOPMENTS IN WILLIAMS TYPE STORAGE
Joseph M. Wier

VIII PERSONNEL

The personnel associated with the group and hence the contributors to this report are:

Brown, Caroline
Clutterhan, D. R.
Cobb, Bessie (1/2 time)
Gibson, Margaret
Gregory, R. T. (1/2 time)
House, Natalie R.
Huffman, W. L.
Jarrett, T.
Jones, W. E.
Kerkering, T. E.
King, Richard (1/2 time)
Kudlich, R. A. (1/2 time)
Leichner, G H. (1/2 time)
Lopeman, N. E.
Meagher, R. E.
Michael, G. W.
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UNIVERSITY OF ILLINOIS

GRADUATE COLLEGE

DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

February 16, 1953 - March 15, 1953

I MATH GROUP ACTIVITY (This is supported in part by ONR Task 30)

The originally planned computation on the curved shock problem has been completed. Results indicate the need for running portions for intermediate parameters which were not expected to be needed. This is necessary to locate more precisely a transition in the graphs. The areas in question will require a considerable amount of computing time to supply results of the desired accuracy.

The program for solving the refraction problem (a plane shock wave incident upon a gaseous interface and producing reflected and refracted waves) has been written up and will be placed in the library. The code can be used with parameters giving shock strength and gas characteristics.

A double precision program of the interpretive kind has been added to the library. This is Code 45. A multiple precision floating point program has also been completed. This interpretive routine works to 70 binary digits (21 decimal digits) using a floating binary representation in the machine. Input and output are in floating decimal form with the exponent ranging over the values -36 to +36. This program (referred to as the 1.8 Precision Routine) will not be added to the library because it contains an order (F0) which will be obsolete when certain control changes are made. A new version is being prepared.

Studies on convergence of solutions of partial differential equations are continuing using Laplace's equation. The number of iterations required for convergence of Frankel's extrapolation of the Liebmann method are being determined.

Further work on read-around tests has been done, and several new read around codes were written. Modifications include:

a) Not checking spots in serial fashion but skipping in the test procedure to, say, the 9th spot ahead each time.

b) Printing results decimally

c) Testing on a field of dashes

d) Eliminating the feature permitting tests on a 512-word memory.

Recent changes in the memory (see Section IV) have increased the read-around ratio so much as to make existing read-around programs almost useless. A new code is now being written which will take new characteristics into account and will sense both changes to zeros and changes to ones in the course of a test. Meanwhile a code has been written to do testing until the other is complete.

The internal report on metric properties of Boolean algebra has been finished and four of the sevel chapters have been typed.

During the past month the following new programs have been added to the library:

45. Double precision arithmetic

76. Sum memory and check. This program is an interlude which sums the memory before the main program is run. It is intended for use on long program tapes which are used frequently.

77. Arctangent in degrees. This program is used with an arctangent routine.

1.8 Precision Floating Point. This program will be available for use but will not be put in the library.

The following list gives problem specifications for new codes which were tried during the month. It does not indicate how the machine was used because problems with numbers less than 112 may have consumed large amounts of machine time.

NUMBER	PROBLEM SPECIFICATION	AFFILIATION
112	Topological invariants in configuration matrix	Math
113	1.8 Precision Routine	Computer
114	Read-around test	Computer
115	Vibrating cylinder problem	Physics
116	Sum memory and check	Computer
117	Electron trajectories	Elec. Engr.
118	Logical algebra for circuit simplification	Computer
119	Path-length distribution in random walk	Computer
120	Solve 8 simultaneous algebraic linear equations	Chem. Engr.
121	Demonstration problems for coding and programming class	Computer
122	Chi square analysis	Psychology

II USE OF THE COMPUTER

Table I shows the distribution of machine time for the interval February 16 through March 15, 1953.

TABLE I

	TIME
Engineering Time 8-12	42:11
Engineering Time at other Times	26:44
Idle	2:27
Read-around ratio	20:33
Leapfrog	71:33
COMPUTER GROUP	
Wheeler	8:42
Nash	:35
Leichner	2:26
Clutterham	87:18
King	3:49
Cobb	1:48
Muller	2:05
Others	3:22
Classes	2:10
Physics	8:59
Control Systems Lab	32:30
Civil Engineering	:53
Psychology	19:39
Electrical Engineering	2:26
Math Statistics	:16
Chemical Engineering	2:59
Mathematics	8:01
Demonstrations	2:38
Total Hrs. in Use	354:04

III ERROR FREQUENCY AND PERFORMANCE

The machine is normally used for "engineering" and maintenance between 8 AM and 12 N, and for a check of its performance between 4:30 PM and 5:00 PM of each weekday. Since the periods between 8 in the morning and noon, together with certain other irregular periods like Saturdays

and Sundays, are devoted to a heterogeneous group of functions, it is more instructive from an error analysis standpoint to look at the periods between noon and midnight of each weekday in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind a summary table has been prepared using the period between noon and midnight of each weekday. This table lists the running time when the machine was operating properly, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 4:30-5:00 period (when the machine is checked) if no errors are found, the time is given to the "running O.K." column. Each failure was considered to have terminated a running period and was followed by a repair period to be consistent in the method of preparing this Table. Since the leapfrog code is very probably our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented as Table II.

DATE	RUNNING OK	REPAIRS	DURING OK TIME	TYPES OF FAILURE CAUSING REPAIR TIME	WAS FAILURE FIXED?	WASTED	LEAPFROG	FAILURES OF LEAPFROG
2/16/53	10:43	1:14	3	Memory error 2^{-4} Memory error 2^{-25} Memory error 2^{-4}	No Yes Yes	:03	1:56	3
2/17/53	11:41	:19	1	Low intensity tube #19	Yes	0	2:48	1
2/18/53	11:28	:31	2	Flaw 2^{-4} Flaw 2^{-28}	Yes Yes	:01	1:41	2
2/19/53	11:01	:54	3	Flaw 2^{-4} Comparison Test Flaw 2^{-28}	Yes Yes Yes	:05	3:39	3
2/20/53	11:00	:26	0			:32	2:12	0
2/23/53	11:47	:07	0			:06	:45	0
2/24/53	12:00	0	1	Error not found	No	0	3:41	0
2/25/53	11:59	0	1	Sprocket hole ignored due to tape and light intensity tolerance	No	:01	1:40	0
2/26/53	8:23	2:14	1	Printer Control	No	1:23	:25	0
2/27/53	11:08	:52	2	Grounding wire on reader broken Flaw 2^{-19}	Yes Yes	0	1:08	1
3/2/53	12:00	0	0			0	3:25	0
3/3/53	10:41	1:19	2	Comparison test 2^{-31} memory 3 shorted tube in counter	Yes Yes	0	1:59	1

DATE	RUNNING OK	REPAIRS	DURING OK TIME	TYPE OF FAILURE CAUSING REPAIR TIME	FAILURE FIXED?	WASTED	LEAPFROG	FAILURES OF LEAPFROG
3/4/53	10:52	1:08	3	Broken pin c tube in dispatch counter Changed tube in address generator-open filaments Punch error	Yes Yes No	0	:49	3
3/5/53	12:00	0	0			0	1:31	0
3/6/53	11:51	0	0			:09	1:57	0
3/9/53	------	-----	------	Memory changed on Saturday March 7, 1953. March 8-9 used for adjustments	------	------	-------	------
3/10/53	11:32	:28	2	Memory failure position 23 Adjusted printer control	Yes Yes	0	2:33	1
3/11/53	11:42	:16	1	Changed chassis #23	Yes	:02	4:16	1
3/12/53	11:57	0	0			:03	2:59	0
3/13/53	11:43	:15	1	Low intensity on tube 30	Yes	:02	1:08	0
TOTALS:	215:28	10:05	23		5 NO 18 YES	2:27	40:32	16

IV COMMENTS ON MACHINE

A. Memory

During the month six cathode ray tubes were changed in the machine memory. Three of these tubes were changed to improve the RAR in the machine, two were changed because of flaws and one was changed for an indirect reason which will be explained later.

Two chassis were changed during the month. One of these was changed because random errors were found in it. The first amplifier tube had intermittent short circuits; the other chassis was changed because a leaky (oil) condenser was found. The chassis was changed even though no errors were produced by the leakage of oil.

On Saturday, March 7 the memory sensing system used in the ILLIAC was considerably altered. The sensing system installed at this time is based upon a suggestion made by Mr. Thorenson of the SWAC and, very briefly, senses the dot or dash at the time location corresponding to the second spot. Because of the way in which our present memory circuit is designed the system now being used is actually a three dot Williams memory system with the sensing taking place in the second dot position. The difference between a dot and a dash depends upon whether or not the beam is turned on in the position of the third spot (which is also at the location of the first spot). A more detailed description of this arrangement will be available in a report soon. Prior to this change the memory has been operating with a minimum RAR of 30 using our standard RAR routine.

With the change which has been recently incorporated, the RAR is a minimum of 80. It required two days after the memory was altered to make all of the necessary changes and adjustments and to eliminate the flaws.

One tube was removed because its cut-off characteristic was much less "sharp" than the others. This appeared to be important in the new sensing system and would not have been changed otherwise.

B. Input-Output

The difficulties occuring with the input-output during the previous month have been largely eliminated.

C. General

The machine has operated about 2513 hours to date. The total number of tubes (excluding cathode ray tubes) which have been recorded as failures during this interval is 93.

V RESEARCH AND DEVELOPMENT (Supported in part by ONR Task 24)

A new circuit has been designed which permits a greater degree of flexibility in testing of transistor characteristics. Tests are now being made to observe the speed with which certain of the transistor characteristics respond to changes in other parameters.

A logical diagram of the drum circuitry has been drawn. A sample recording circuit and playback circuits have been made and tested. Some difficulty is still present involving the tolerances of the signals received from the reading heads. In some of the reading heads the signals received on playback at the highest recording density expected (108 bits

per inch) is only about 0.4 of the signal obtained at much smaller recording densities. On other heads this factor is about 0.6. A study is being made of all the heads available.

For purposes of amplifying the playback signal and distinguishing it from the switching and recording signals there are currently two short time constants designed in the amplifier system. These time constants cannot be the same without producing a rather considerable amount of overshoot. This may force us to require a larger waiting time between a record order and a read order than between two read orders.

Plans are being made to reduce the operation time for an addition order by gating straight down from R^1 to R_1 in the accumulator thus reducing the time required for an addition order by a shift time of 16 μseconds. This change contemplates the use of gate tubes already installed in the RI registers and which are now being referred to as the "orange gate". Changes to be made when the new arithmetic control is installed will provide for two new types of orders characterized by the A function digits F and K. The orders are the same as the L and S orders, except that the carry insertion into the least significant stage of the adder is reversed for the F and K orders; that is, a carry digit is inserted during an addition and is not inserted during a subtraction.

Examples: F5 N Replaces NR_1 by $N(n) + 2^{-39}$

K1 n Replaces NR_1 by the digitwise complement of NR_2.

The status of the drawings for this change is as follows:

L-491	Logic of Control for Arithmetic	
S-490	Gate Driver RII)	Not checked - Replaces S-171
S-487	Driver Chassis)	

The following drawings will have to be redrawn:

L-244	Arithmetic Control	(The rough drawing is complete)
S-201	Gate Driver RI	" " " " "

The following drawings will require changes:

M-343	Arithmetic Stop Chassis
L-396	End Connections
M-181	Shift Sequence Chassis (All circuits designed)
L-422	Decoding Chassis
L-428	Memory Control
L-359	RI Register
L-467	Adder (Circuits for half-adder not designed)

VI CONSTRUCTION

1. Circuits for drums
    - a. Gating control (M-478)
    - b. Clear Driver and origin synchronization (M-476)
    - c. Primary matrix (M-471)
    - d. Record gating (M-484)
    - e. Playback gating (M-477)
    - f. Coincidence (M-472)
2. Experimental circuits for drum
    - a. 815 and pre-amplifier chassis
    - b. Model of main drum amplifier
3. Slow speed input using Western Union reader at 15 sexadecimal characters per second.
4. Model of photoelectric tape reader for tape comparison.

VII SEMINARS

February 25, 1953
INTERACTION OF CURVED SHOCKS
D. R. Clutterham

March 4, 1953
LEAPFROG II
D. J. Wheeler

March 11, 1953
MULTIPLE PRECISION ROUTINES
Miss Bessie Cobb

March 18, 1953
DIGITAL COMPUTER METHODS FOR SOLVING LINEAR ALGEBRAIC EQUATIONS AND FINDING EIGENVALUES AND EIGENVECTORS
J. P. Nash

VIII PERSONNEL

The personnel associated with the group and hence the contributors to this report are:

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Kudlich, R. A. (1/2 time)
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R. E. Meagher

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3/25/53

UNIVERSITY OF ILLINOIS

GRADUATE COLLEGE

DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

March 16, 1953 -------------- April 15, 1953

I MATH GROUP ACTIVITY (This is supported in part by ONR Task 30)

About four more hours of computing time should finish the curved shock problem. Two final runs near extreme values of the pressure ratio across the incident shock were made and now there remain only a few roots to be re-run to obtain their associated quantities.

Work is being done on coding Poisson's equation in two dimensions for an arbitrary region. Half-precision numbers are being used so as to double the number of available grid points.

The new multiple precision floating point program is being checked. Besides containing no obsolete orders this program differs in several respects from the one being used now. The output (which can be 20 decimals) is rounded off, and it is possible to specify the number of places printed by the address of the print order. The present program has a fixed number of printed digits specified by a preset parameter and prints an unrounded answer.

A new read around test has been completed and is now being used. It has the following characteristics, many of which are similar to the old tests we have used:

a. Each address of the memory is tested for failures from one to zero and from zero to one.

b. The next spot to be tested is 19 places removed from the previous spot tested. This procedure of testing by steps of 19 is continued until half the memory has been tested. Then the code is moved to the tested half of the memory and the other half is tested.

c. The print-out indicates the number of bombardments made (decimal), the type of failure, the spot being bombarded when failure occurred (sexadecimal), and the cathode ray tube on which failure occurred (decimal). The type of failure is indicated by printing zero for the zero to one failure and L for the one to zero failure.

d. The number of bombardments n desired is a multiple of 10 and is punched on the input tape as n/10. After each complete test of the memory the tape is read.

e. A one to zero failure from 100 bombardments at address 2F3 on tube 27 would be indicated as follows:

```
100
L  2F3  27
```

More extensive investigations of the simplification of multiple output switching circuits have been made. When circuits are represented as polynomials in Boolean algebra, it is possible to generalize any simplification procedure to the multiple output case. No modification of the procedure is needed in the two output cases.

Several simplification processes have been written as programs for the ILLIAC. The most successful of these has been prepared in a form for general use. The systematic part of the Harvard Computation Laboratory minimizing chart procedure has been prepared as a program for general use.

Extension of minimizing processes to the case of redundant input information has been made but no ILLIAC program has as yet been prepared.

Students in the programming and logical design classes are making use of the ILLIAC as a regular part of their assigned class work.

During the past month the following programs have been added to the library, numbers 80 and 82 being prepared by Professor J. N. Snyder of the Physics Department.

78 Laplace's equation - Liebmann method.

The program finds a solution for an arbitrary two dimensional region. The maximum number of boundary and interior points is about 950 for very simple boundaries.

79 Refraction Code.

When a plane shock wave is incident upon an interface between two gases of different densities and specific heats a configuration consisting of the incident shock, a transmitted shock, and a reflected shock results. Given a set of parameters characterizing the gases and the strength and position of the initial shock, this program computes limits for the position of the reflected shock and other quantities characterizing the three shock configuration.

80 Minimization of a function of two variables.

This program uses a gradient method for finding the minimum value.

81 Logical Algebra.

This is an 87-order interpretive routine for aiding in the design of switching circuits. It permits manipulation of Boolean algebra expansions and simplifies the preparation of simplification programs for the machine

82 Legendre polynomials.

This program uses a recurrence relation to compute $P_0(x)$, $P_1(x)$, . . ., $P_n(x)$ for a given value of x. It is a closed subroutine entered with x in the accumulator and having n specified as a parameter upon entry.

The following list gives problem specifications for new codes which were tried during the month. It does not indicate how the machine was used because problems with numbers less than 123 may have consumed large amounts of machine time.

NUMBER	PROBLEM SPECIFICATION	AFFILIATION
123	Matrix coefficients for skewed plate analysis	Civil Engineering
124	Find 1.8125 power of a number	Computer
125	Compute mean scattering angle for tracks in photographic plates	Physics
126	Eigenvalues by direct matrix reduction	Computer
127	Scattering length and intrinsic range for an arbitrary central potential	Physics
128	Solution of 2 simultaneous cubic equations with various parameters	Civil Engineering
129	Programmed division	Computer
130	Calculation of phi coefficients for 183 variable matrix	Agr. Econ.
131	Check dichotomous data	Psychology
132	Computations for simply supported beam with dynamic load	Civil Engineering
133	Correlation matrix factor analysis	Medical School
134	Experiments with relaxation methods	Computer
135	Check point code	Computer
136	Special counting routine	Civil Engineering
137	Dynamic response of simple structures	Civil Engineering
138	Special double precision print routine	Civil Engineering

NUMBER	PROBLEM SPECIFICATION	AFFILIATION
139	Dynamic response studies	Civil Engineering
140	Non-uniform magnetic field study	Physics
141	Study of superconductivity in metals	Physics

II USE OF THE COMPUTER

Table 1 shows the distribution of machine time for the interval March 16 through April 15, 1953.

TABLE I

Engineering 8-12 AM	31:03
Engineering 1-12 PM	9:46
RAR	28:17
Leapfrog	78:45
Idle	1:52
COMPUTER GROUP	
Wheeler	10:04
Nash	:23
Robertson	:19
Gillies	11:35
Clutterham	53:01
King	2:22
Cobb	1:08
Muller	3:35
Others	3:46
Classes	4:05
DEPARTMENTS USING MACHINE	
Physics	37:03
C.S.L.	49:42
Civil Engineering	30:13
Psychology	12:06
Institute of Communications Research	10:08
Mathematics (Statistics)	1:21
Agriculture	5:34
Chemical Engineering	3:38
Mathematics	:27
Institute for Juvenile Research	:20
Demonstrations	2:47
Total Hours On:	402:56

III ERROR FREQUENCY AND PERFORMANCE

The machine is normally used for "engineering" and maintenance between 8 AM and 12 N, and for a check of its performance between 4:30 PM and 5:00 PM of each weekday. Since the periods between 8 in the morning and noon, together with certain other irregular periods like Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more instructive from an error analysis standpoint to look at the periods between noon and midnight of each weekday in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind a summary table has been prepared using the period between noon and midnight of each weekday. This table lists the running time when the machine was operating properly, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 4:30-5:00 period (when the machine is checked) if no errors are found, the time is given to the "running O.K." column. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this Table. Since the leapfrog code is very probably our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented as Table II.

DATE	RUNNING OK	REPAIRS	FAILURES DURING OK TIME	TYPES OF FAILURE CAUSING REPAIR TIME	WAS FAILURE FIXED?	WASTED	LEAPFROG	FAILURES OF LEAPFROG
3/16/53	11:29	:26	3	0 → 1 pos 6 add 0 3 F	Yes	:05	1:06	2
				0 →1pos 18 add S F	Yes			
				Machine error, cause unknown	No			
3/17/53	10:56	1:02	2	Differences between two successive runs, with same tape.	No	:02	1:14	0
				Suspicious print layout 0 →1 pos 2 add 190 Indicated by P.M.	No			
3/18/53	11:40	:20	2	Fuse flew +150v	No	:04	1:04	1
				Leapfrog Input-output failure holes not punched clear of chad	No			
3/19/53	11:27	:29	1	Regeneration counter error	Yes (but later)	:04	1:56	0
3/20/53	11:56	:00	0			:04	1:23	0
3/23/53	11:58	:00	1	Punch error 1 zero instead of 2	Yes	:02	2:08	0
3/24/53	10:57	1:03	1	Input-output error	Yes	:00	2:30	1
3/25/53	11:58	0	0			:02	1:23	0
3/26/53	11:53	:07	1	100v fuse blew (reader trouble suspected	No		1:05	0
3/27/53	11:04	:56	3	Input error	No	:00	:52	0
				Input error	No			
				Input error	No			

DATE	RUNNING OK	REPAIRS	FAILURES DURING OK TIME	TYPES OF FAILURE CAUSING REPAIR TIME	WAS FAILURE FIXED?	WASTED	LEAPFROG	FAILURES OF LEAPFROG
3/30/53	11:39	:17	2	Memory failure pos 30 Intensity too low	No	:04	1:40	0
				Same as above	Yes			
3/31/53	11:31	:29	2	Pos 2^{-12} machine error	Yes	:00	1:20	0
				Data indicates error	No			
4/1/53	10:37	1:20	1	Pos 2^{-12} 1 → 0. Tube in pos 12 replaced	Yes	:03	1:19	0
4/2/53	10:35	1:19	1	"Hang up"on a 66 order tube 26 and 30 in chassis replaced.	Yes	:06	:29	0
4/3/53	11:57	:00	0			:03	:20	0
4/6/53	12:00	:00	0			:00	:50	0
4/7/53	11:11	:49	1	"Hang up"due to $BGR_2 < 4$ volts	Yes	:00	1:21	0
4/8/53	12:00	:00	0			:00	:34	0
4/9/53	10:38	1:22	1	Power relays off	No(?)	:00	2:48	0
4/10/53	11:11	:44	2	"Hang up"on input	No	:05	1:21	0
				1 → 0 pos 33 add 042	Yes			
4/13/53	11:52	:06	0			:02	:55	0
4/14/53	11:46	:14	2	Routine changed in memory	No	:00	11:05	2
				0 → 1 pos 5 adjusted #5	Yes			
4/15/53	11:50	:06	1	Reader error	No	:04	:26	0
Totals	264:05	11:09	27		12 Yes 15 No	:50	29:09	6

IV COMMENTS ON THE MACHINE

A. Memory

During the month it was found necessary to change four cathode ray tubes. One cathode ray tube was changed to improve the RAR; one cathode ray tube was changed because of a flaw; one cathode ray tube was changed because the required cut-off voltage became very high for reasons unknown and the fourth cathode ray tube was changed because the signal size at the screen became very small for reasons unknown.

One chassis was removed for repairs during the month.

The memory continues to operate with the memory system as altered on March 7th giving a minimum RAR of 80. The RAR was tested for failures from 0's to 1's as well as for 1's to 0's. The test for RAR is now being carried out using the new routine which is fully described in Section I.

B. Input-Output

Some trouble has again been experienced during the month in reading information into the machine. Although this is believed to be a tolerance problem associated with the location of the tape holes and the light admitted to the photocells in the tape reader, it has not been possible to obtain failures sufficiently often to adequately diagnose the difficulty. Each time an input test is made it appears impossible to obtain errors unless the light bulb intensity is abnormally low, or the paper tape is mutilated or worn in some way or other. A

small regulating transformer has been added to make the light intensity for the tape reader independent of line voltage although there is no indication that changes in line voltage have been the source of the errors.

C. General

The machine has been operated about 2920 hours to date. It was found desirable to change 12 5687's in the gate drivers during the month in order to keep the gate voltage tolerances within reasonable limits.

A periodic check of the tolerances in the B+ and filament voltages is being made by the system of marginal checking while the machine is running the Leapfrog II routine. This has indicated that the tolerance bands of these voltages have been getting somewhat smaller during the past month. This has been due partly to the gate voltage tolerances as a result of the aging of the 5687's and also to the change of characteristics in the new logical adder. An addition of one resistor in the complement gate circuit is anticipated as well as a check of the tolerances in the adder.

A new high speed punch for the output of the machine has been finished but has not been tested. This will be used interchangeably with the present punch.

D. Tape Preparation Facilities

A new tape comparator unit is available for checking one tape with respect to another at the rate of 10 characters per second. The unit consists of two Western Union tape readers and relays.

V RESEARCH AND DEVELOPMENT (Supported in part by ONR Task 24)

A. Transistor Circuits

The tests on the response time of transistors to fast waveforms have largely been completed. Considerable evidence has been obtained leading to the following conclusions regarding the type 1698 transistor:

(1) The delay in increase of collector current is not excessive for any of the operating conditions used, and was relatively constant among the nine transistors tested. For a rise time in emitter current of one microsecond, the rise time of the collector current was from about 1.0 to 1.5 microseconds.

(2) The delay in decrease of collector current varied over a considerable range depending upon both operating conditions and the transistor involved. For all nine transistors, the fall time of the collector current was one microsecond or less, provided that the high-current point was in the linear regions of the collector characteristics. When the high current point is moved into the non-linear portions of the curves (for instance, by increasing collector load resistance with constant collector supply voltage), the delay time begins to increase very rapidly to values in excess of twenty microseconds.

These results indicate that the saturation (i.e., high emitter and collector current) region of the characteristics cannot be utilized as a uniform end-point.

The circuits of the transistor characteristic tracer were modified to improve the accuracy of the curves produced and the range of currents to be used.

B. Drum Circuits.

The amplitudes of the play-back signals from recordings at 80KC and 8KC were measured for all of the drum heads. Of the 219 heads supplied with the drum, 6 have open windings and 7 have signals which are either too small or are otherwise unsuitable. It has been found necessary to increase the coupling time constants in the play-back amplifying system. This change seems to indicate that the recovery time constant from the switching transient is about 350 microseconds, and the recovery time from a recording transient is 450 microseconds.

C. Memory Sensing Studies.

Additional work has been carried out to compare the "Thorenson" system of storage with the system now in use in the ILLIAC. These tests seem to indicate that the present RAR in the ILLIAC of 80 might increase to about 150 if the necessary rewiring were done to incorporate the "Thorenson" system into the machine. However, it appears that the difference between the two systems may be a detailed one depending upon the cathode ray tube design. Although the figure of 150 quoted here for the "Thorenson" system RAR appears to be better than the RAR obtained in the machine at the present time, tests on 25 new RCA tubes developed for storage use for the Bureau of Ships indicate that with these better tubes the RAR would be higher with the present ILLIAC system than with

the "Thorenson" system. Internal Report No. 45 describes the present ILLIAC system and a report will be available soon on the tests of the RCA tubes.

VI CONSTRUCTION

1. Tape Comparator using Western Union Readers.
2. Covers for spare -2000 volt supply painted.
3. Tape boxes for comparators.
4. Added regulating transformer to Ferranti AC supply.
5. Four playback amplifier for drum memory.
6. Tested 470 5687 tubes; 300 12AU7; 600 6AL5.
7. Output punch for computer completed except for covers.
8. Model of photoelectric tape reader built and has been operated at approximately 38 inches per second tape speed with the ability to stop in 1/20 of an inch.

VII SEMINARS

March 25, 1953
READING DIGITAL INFORMATION FROM THE ILLIAC DRUM
R. E. Meagher

April 8, 1953
AN INTRODUCTION TO LOGICAL CIRCUITS USING TRANSISTORS
R. A. Kudlich

April 13, 1953
ERRORS IN ITERATIVE SOLUTIONS OF LINEAR ALGEBRAIC SYSTEMS
A. S. Householder (Visitor from Oak Ridge National Lab)

April 15, 1953
CONVERSION PROGRAMS OR "AUTOMATIC PROGRAMMING"
D. J. Wheeler

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Meagher, R. E.
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Muller, D E.
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R. E. Meagher.
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4/27/53

UNIVERSITY OF ILLINOIS

GRADUATE COLLEGE

DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

April 16, 1953 - May 15, 1953

I MATHEMATICAL RESEARCH AND CODING (This is supported in part by ONR Task 30)

The computations for the curved shock problem have been finished and the problem is now being written up.

The multiple precision floating point program (called 1.7 Precision) is now in the library.

Revision of certain post mortem routines to reduce the temporary storage has been found desirable, and codes 56, 57 and 59 have been changed to make them more useful and so that external temporary storage agrees with that used by the Decimal Order Input (Code 18).

A code for Poisson's equation has been completed and tested successfully with several typical problems. A routine for computing a parameter which ensures rapid convergence of the iteration process is now being written as an additional feature.

A new consolidated engineering tape has been completed and is being used routinely to test the computer. This test consists of a printer test, the new read-around test (described in the April report) and the new leapfrog (described in the February report). The printer test is a more exacting one than that used before. It prints each character in the order 0 L 1 F 2 J 3 N 4 S 5 K 6 9 7 8 along with a space and a carriage return - line feed. The characters 0 and L are printed by means of 92 orders while the others are printed by means of 82 orders.

A more effective code for the simplification of polynomial expressions in Boolean algebra is being used. It requires more machine time than the previous code.

The program library has been divided into two parts, the engineering codes being put into a separate group. These codes are of limited interest

outside of the laboratory.

During the past month the following programs have been added to the library. Taken with Code 80, Codes 84, 85 and 86 make a set of minimization programs. They were all written by Professor J. N. Snyder of the Physics Department.

83. Check Point Routine.

This program is intended primarily to help a programmer trouble-shoot his code. It uses the blocking order principle and supplies a wide variety of information the nature of which can be pre-specified by the programmer.

84. Minimization of a function of four variables.

85. Minimization of a function of n variables.

These two codes use a gradient method for minimizing.

86. Minimization of a function of n variables by treating one variable at a time.

This program utilizes a crude approach which may require a long time. However, in cases where the gradient is small with respect to some argument, the other minimizing codes may be ineffective. In these cases the problem may be roughed out with one of the steepest descent codes and finished with Code 86. Parameters, entry and storage locations of Codes 85 and 86 are arrnaged to facilitate

use of the two codes together.

87. 1.7 Precision Floating Point.

This code has been described in earlier reports.

II NEW PROBLEMS LISTED FOR THE MACHINE

The following list gives problem specifications for new problems which were tried during the month. It does not indicate how the computer was used because problems with numbers less then 142 may have consumed large amounts of machine time.

NUMBERS	PROBLEM SPECIFICATION	AFFILIATION
142	Real roots of 12 7th degree algebraic equations	Math
143	Calculate X^2 for dichotomous data	Psychology
144	Response pattern analysis	Psychology
145	Solution of a set of linear algebraic equations	Physics
146	Two dimensional Poisson equation	Computer
147	Post mortem routines	Computer
148	Spaced loop antenna patterns	Elect. Engr.
149	Principal axis factor analysis	Psychology
150	Lucas test for primality of $2^{\overset{8191}{\cancel{9181}}}-1$	Computer
151	Tchebyscheff polynomials	Elect. Engr.
152	Matrix multiplication	Computer
153	Ranked numbers	Psychology
154	Shock curvature ratios	Computer
155	Accelerated Laplace convergence	Computer

III USE OF THE COMPUTER

Table I shows the distribution of machine time for the interval April 16 through May 15, 1953:

TABLE I

Engineering 8-12 AM	34:09
Engineering 12 Noon-12 Midnight	26:36
R.A.R.	20:47
Leapfrog	64:20
Wasted	1:24
Digital Computer Laboratory	
Wheeler	28:16
Nash	:25
Clutterham	6:06
King	1:44
Cobb	3:57
Muller	17:47
Others in Group	3:17
Classes	9:26
Departments Using Machine	
Physics	45:24
C. S. L.	41:04
Civil Engineering	7:31
Psychology (Wrigley)	17:27
Electrical Engineering	11:43
Institute of Communications Research	:19
Mathematics (Statistics)	3:23
Agriculture	1:36
Chemical Engineering	9:00
Mathematics	1:10
Psychology (Kamman)	:45
Demonstrations	6:56
Total:	364:32

IV ERROR FREQUENCY AND ANALYSIS

The machine is normally used for "engineering" and maintenance between 8 AM and 12 N, and for a check of its performance between 5:00 PM and 5:30 PM of each weekday. Since the periods between 8 in the morning and noon, together with certain other irregular periods like Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more instructive from an error analysis standpoint to look at the periods between noon and midnight of each weekday in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind a summary table has been prepared using the period between noon and midnight of each weekday. This table lists the running time when the machine was operating, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 5:00-5:30 period (when the machine is checked) if no errors are found, the time is given to the "running column". Each failure was considered to have terminated a running period and was followed by a repair period in preparing this Table. Since the leapfrog code is very probably our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented as Table II.

DATE	RUNNING	REPAIRS	RUNNING TIME	TYPES OF FAILURES	FAILURE FIXED?	WASTED	LEAPFROG	OF LEAPFROG
4/16/53	10:45	1:15	3	1. Tape ran through reader on leapfrog	No			
				2. $0 \rightarrow 1$ at 2^{-30}	Yes	:00	:15	1
				3. Input error	No			
4/17/53	11:59	:00	0			:01	:14	0
4/20/53	:00	12:00	1	Error in leapfrog while checking voltage tolerances. Machine time cancelled.		:00	:00	1
4/21/53	11:58	:00	00			:02	:43	0
4/22/53	11:14	:41	3	1. Tape reader tolerance off	No			
				2. Intensity on tube 37 low	Yes	:05	1:02	2
				3. Tube 12 pos 3F1 or 3F3	Yes			
4/23/53	11:27	:33	2	1. Punch not operating correctly.	Yes	:00	:38	1
				2. Reader error	Yes			
4/24/53	11:59	:01	1	Unknown	No	:00	1:40	1
4/27/53	11:58	:01	1	Punch error.	Yes	:01	:39	0
4/28/53	11:21	:37	2	$0 \rightarrow 1, 2^{-15}$ add 0J3 plus 0K4	Yes	:02	3:04	1
				$0 \rightarrow 1, 2^{-15}$ add 0SK	Yes			
4/29/53	10:33	1:26	5	1. Reader light burned out	Yes	:01	6:14	4
				2. Probably memory error	No			
				3. Punch failed to punch clearly	Yes			
				4. $0 \rightarrow 1$ pos 16, add 35F	No			
				5. $0 \rightarrow 1$ pos 25 3L'	No			

DATE	RUNNING	REPAIRS	RUNNING TIME	TYPES OF FAILURES	FAILURE FIXED?	WASTED	LEAPFROG	OF LEAPFROG
4/30/53	9:51	2:07	2	1. 300v. Power supply off	No	:02	3:05	1
				2. Wire on reader broken	Yes			
5/1/53	10:18	1:41	3	1. Punch error	No	:01	1:31	1
				2. Punch error	Yes			
				3. Unknown	No			
5/4/53	11:49	:08	1	Chad packs in chute, cuts tape	Yes	:03	:48	0
5/5/53	11:47	:13	1	Failed pos 7	No	0	:52	1
5/6/53	11:33	:27	1	$0 \rightarrow 1\ 2^{-15}$ at 202	Yes	0	:33	1
5/7/53	10:36	1:22	5	1. $0 \rightarrow 1$ pos 9, 0JL	Yes			
				2. Arithmetic error	No			
				3. Flaw pos 20 add }1F	Yes	2	2:11	5
				4. Change occurred in routine	No			
				5. $0 \rightarrow 1\ 2^{-4}$	No			
5/8/53	11:55	:05	1	$0 \rightarrow 1$ pos 9 at odd 0		1	3:28	0
5/11/53	10:06	1:54	7	1. Punch spring broken	Yes			
				2. Div. failure $1 \rightarrow 0\ 2^{-10}$	No			
				3. Mult. failure $1 \rightarrow 0\ 2^{-26}$	No			
				4. Memory 2^{-37}, 0 to 1 at 07L	No	0	1:44	6
				5. Memory 2^{-12}, 1 to 0 at 3F0	No			
				6. Memory 2^{-37}, $0 \rightarrow 1$ at 09F	Yes			
				7. Memory 2^{-12}, $0 \rightarrow 1$	Yes			

DATE	RUNNING	REPAIRS	FAILURES DURING RUNNING TIME	TYPES OF FAILURES	FAILURE FIXED?	WASTED	LEAPFROG	OF LEAPFROG
5/12/53	10:54	1:06	5	1. Punch failed to punch clean holes	No	:00	:48	0
				2. Punch error	No			
				3. Punch error	No			
				4. Punch error	No			
				5. Punch error	No			
5/13/53	11:49	:11	2	Probably 2^{-16}	No	:00	1:08	0
5/14/53	8:38	3:19	6	1. 0 1 2^{-23} comparison failure	No	:03	2:16	3
				2. 1 0 2^{-7} add .096	Yes			
				3. Machine error	No			
				4. Punch error	No			
				5. Punch error	No			
				6. Comparison failure	Yes			
5/15/53	11:53	:07	1	Error 2^{-12}	No	:00	:33	0
TOTALS:	234:23	29:14	53		29 No 24 Yes	:23	33:26	29

The number of errors is much higher than it has been before. The average running time per leapfrog error is just a little over one hour. The average time for all routines per error is close to 8 hours. The number of memory errors is 23. The number of punch errors is 13. The abnormally large number of memory errors cannot be easily accounted for. The abnormally large number of punch errors is due partly to the wearing out of parts in the original punch and partly to the use of a new punch.

V COMMENTS ON THE MACHINE

A. Memory

During the month six cathode ray tubes were changed. One was changed to improve RAR and five were changed because of flaws. Four of the memory regeneration chassis were changed during the month. Two of these were changed because of filament failures in one tube each, one was changed because of a condenser with an oil leak and one was changed because it was excessively microphonic.

It has been necessary to adjust the intensity on one or sometimes two tubes each morning when the machine is turned on. Occasionally, it is necessary later in the day to adjust the intensity on one of the tubes. These adjustments are most frequently associated with about five of the memory positions and the cause of this is being investigated. There seems to be no good reason why these few memory positions should require extra attention.

B. Input-Output

A new high speed punch built around teletype unit ARPE2 has been placed into operation. It is interchangeable with the older high speed

punch and runs at the same speed.

C. General

The machine has been operated a total of 3,274 hours and approximately 130 tube failures have occurred exclusive of those causing cathode ray tube replacements.

VI RESEARCH AND DEVELOPMENT (Supported in part by ONR Task 24)

A. Transistor Circuits

During the past month some studies have been made of the characteristics of junction diodes, especially with regard to their use in a fast-acting logical type circuit. The diodes concerned included the three types of grown germanium junction diodes received from the Navy, types 1784, 1786 and 1787, and a single sample of a silicon diffused junction diode.

The d-c characteristics of one type 1784 was measured. A very high back-to-front-resistance ratio, of the order of 10^5 was obtained, and reverse voltages of 100 volts were applied without appreciable drop in performance. The three types of grown-junction diodes were tested for rectification properties on sine wave input. At lower frequencies, below 1,000 cycles, the rectification characteristics were outstanding, much better than that of a point-contact diode. However, at higher frequencies the hole-storage effect and distributed capacitance of the diodes caused appreciable overshoot in the reverse direction, and at frequencies of the order of 100KC this overshoot approached the reverse half-cycle of sine wave in amplitude and duration. The conclusion was drawn that these diodes are not applicable where waveforms with rise and fall times less than the order of .1 - .01 milliseconds are involved.

The diffused-junction diode was appreciably better at high frequencies. It was tested using pulses of from four to fifteen microseconds width, with rise and fall times of about one to three microseconds. Overshoot due to hole storage was observed, but of a magnitude which would not prohibit use of the diode. This overshoot was worse with longer pulses, due to the cumulative effect of forward current flow. The response to extremely rapid changes in voltage, say a few tenths of microseconds, which occur infrequently, has not been tested as yet. The response to the shorter pulses was somewhat improved by biasing the diode to the vicinity of the reverse Zener voltage, where the dynamic resistance again becomes very small. This type of operation may be more important with long duration steady state operation.

The flip-flop received from MIT was tested for dynamic operation. The frequencies used for the test were about 10KC and about 120KC prf. The rise and fall times on driving pulses were quite long, so the limiting speed of response of the flip-flop is still unknown. However, with the pulses used, the circuit operated satisfactorily with several different combinations of individual transistors, excluding those received from MIT, and some from each of the two groups (i.e., those received last fall and those received this year) of our own.

Before attempting to modify this circuit for d-c input and output, the maximum speed of response and triggering sensitivity will be investigated further.

B. Drum Circuits

On April 15th a test was made to see if the playback signals from a drum track would vary over an 8 hour period. In addition to these desired

signals, spurious noise signals were observed with amplitudes both larger and smaller than the desired signals and occurring at more or less random times. Since it would not be possible to operate the drum with such noise present, an effort to eliminate it or reduce it to a negligible amount was made during the past month. While progress has been made in reducing it, the noise is still large enough to cause trouble and more work needs to be done.

A Tesla coil is being used as a noise source since otherwise the noise signals occur at too infrequent intervals. A shielded filter was built for the preamplifier d-c and filaments. A filter was put in the d-c to the main amplifier. Bypass condensers were added on several voltage dividers; signal and d-c leads were shielded and the resistor attenuator for the heads was put in a box. Doubtful connections in the 815 chassis were resoldered and copper straps used to replace small ground leads.

At present, if the input to the preamplifier is not connected the noise is sufficiently small not to set the amplifier flip-flop even at maximum gain. Noise from the Tesla coil does cause trouble when the recording 815's are plugged into their sockets.

In order to accelerate the testing of the drum circuits and logic another experimental rack containing samples of the drum circuits is being assembled. It will make possible the recording of information on four tracks of the drum. The ILLIAC itself will be simulated by circuits.

C. Memory Sensing Studies

Experiments have been conducted using new sensing systems to differentiate between a dot and a dash. A circuits was devised to integrate the output of the amplifier during the latter part of the reading cycle of

a normal ILLIAC memory and to use this for sensing the contents of the position in question. This method worked well enough but no net improvement over the normal ILLIAC system was evident.

The latest attempt tries to make more exhaustive use of the information in any given output signal. If a person with microsecond reflexes could judge from the waveshape, he would usually be able to tell if any given signal was from a dot or a dash. This is possible because he could know both the shapes and the amplitudes of the dot and dash signals. Thus, in an attempt to come closer to this ideal, a circuit was devised to compare the output signal with a standard dash signal which was generated in another slightly altered chassis which always contained dashes at all addresses. This circuit creates an output which is a fixed amount positive if the amplifier output is equal to or more positive in the first part of the pulse, and positive if it is equal to or more negative in the second part of the output pulse. In case these conditions are not met, the output is negative an amount proportional to the difference between the amplifier output and the standard dash signal. This output is then integrated over the entire wave and the integral is taken as a measure of the contents of the spot in question. Ideally, of course, it would be desirable to make a point for point comparison but it seems impractical to expect all wave shapes for dashes to be identical.

Only very preliminary results of this test are as yet available since the system has been in operation only about 24 hours, but indications are that RAR failures are all from dots to dashes and the minimum figure may be as much as twice that for the ILLIAC system. As a point of interest

it is to be noted that this method of sensing is very insensitive to changes in sensing time, dash length, dot length and common type disturbances. All of these quantities except the latter have been tried, with remarkable results.

VII CONSTRUCTION

1. Cover for new punch
2. End connection chassis for orange gate change
3. Driver II chassis for orange gate change
4. Arithmetic control chassis for orange gate change
5. Installed plug and table for new punch
6. Parts for 50 adapter sockets for new 3" cathode ray tubes
7. Frame and four chassis for drum memory test unit.

VIII SEMINARS

April 22, 1953

COMPUTERS IN ENGLAND by Robert L. Hulsizer

April 29, 1953

THE E R A 1103 COMPUTER by W. G. Welchman (Visitor from Engineering Research Associates)

May 6, 1953

AVAILABLE MACHINE TECHNIQUES FOR THE SIMPLIFICATION OF SWITCHING CIRCUITS by David E. Muller

May 13, 1953

CODING THE DEUTERON PROBLEM WITH TENSOR FORCES by J. M. Blatt

VIIII INTERNAL REPORTS

The following Internal Reports have been written during the past year and are now available:

No. 32 A Routine for Calculating the Eigenvalues and Eigenvectors of a Symmetric Matrix by D. J. Wheeler - May 9, 1952.

No. 33 Program Organization for the University of Illinois Computer by D. J. Wheeler - May 16, 1952.

No. 34 Selection Tests on 3KP1 Type Cathode Ray Tubes for a Williams Memory by J. M. Wier - May 22, 1952.

No. 35 ORDVAC Order Code by J. P. Nash - June 10, 1952.

No. 36 University of Illinois Order Code by J. P. Nash June 10, 1952.

No. 37 Error Detection and Correction in Binary Parallel Digital Computer by J. E. Robertson - August 1, 1952.

No. 38 Revised Order Code by J. P. Nash and D. J. Wheeler September 23, 1952.

No. 39 How to Calculate the Read Around Requirements of a Code by J. P. Nash - October 14, 1952.

No. 40 Operation Times of the Illinois Computer by E. L. Hughes October 16, 1952.

No. 41 Comparison of 4 IBM Tubes with 3KP1 Tubes for Williams Memory Use by J. M. Wier - December 4, 1952.

No. 42 Operation Times of ILLIAC by J. M. Wier - January 29, 1953.

No. 43 Calculation of e by the ILLIAC by D. J. Wheeler - February 26, 1953.

No. 44 Controls of the ILLIAC and Input and Output Equipment by D. J. Wheeler - March 10, 1953.

No. 45 Recent Improvement of ILLIAC Memory by J. M. Wier March 25, 1953.

No. 46 Metric Properties of Boolean Algebra and Their Application to Switching Circuits by D. E. Muller - April 15, 1953.

No. 47 Results of Tests on 25 Bureau of Ships - RCA Developmental Williams Memory Tubes - Type C77376B by J. M. Wier April 29, 1953.

X PERSONNEL

The personnel associated with the group and hence the contributors to this report are:

Brown, Caroline
Clutterham, D. R.
Cobb, Bessie (1/2 time)
Ehrlich, George
House, Natalie R.
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King, Richard (1/2 time)
Kudlich, R. A. (1/2 time)
Lopeman, H. E.

Meagher, R. E.
Michael, G. W.
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Stone, David E.
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REM/nrh

UNIVERSITY OF ILLINOIS

GRADUATE COLLEGE

DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

May 16, 1953 - June 15, 1953

I MATHEMATICAL RESEARCH AND CODING (This is supported in part by ONR Task 30)

David R. Clutterham, who has been doing research on shock waves, has completed his work and will receive his Ph.D. this month. The results he has obtained will be published.

A matrix multiplication program is now being used. It accepts matrices punched by rows and furnishes the product in a form which can be read back for further multiplications. The largest square matrices which can be multiplied are 21 by 21.

Multiple output circuits have been shown to be reducible to single circuits provided that the circuits are representable as polynomials in Boolean algebra. The logical algebra subroutine is being rewritten so as to provide greater speed and flexibility.

During the past month the following new programs have been placed in the library. Code 89 was written by Dr. R. M. Brown of the Control Systems Laboratory.

88. Input a sequence of decimal fractions. 26 words

This program is similar to Code 23, but it inputs a signed 12 decimal place number rather than only 11 places.

89. Loop cycling control. 21 words

This program will arrange the cycling around a loop of orders and the programmer may use it rather than furnish a counting routine for each loop in his program.

90. Constant listing auxiliary. 21 words

This program, used with Code 18, lists constants as they are required in a program. When the programmer uses a constant, he writes the constant and not its address. Code 90 places the constant in a list and puts its list address in the appropriate order. The list is not redundant.

91. Matrix multiplication 62 words without output 73 words with output

    This program multiplies an $m \times n$ matrix and an $n \times p$ matrix to give an $m \times p$ matrix subject to $mn + mp + n \leq 949$ if output is required. Matrices are punched by rows and results are output by rows in a form acceptable for input again.

92. Floating decimal square root auxiliary. 16 words

    This program is used with floating point Code 63. It takes the number a from the floating accumulator of Code 63 and replaces it with $\sqrt{a}$.

II NEW PROBLEMS LISTED FOR THE MACHINE

The following list gives problem specifications for new problems which were tried during the month. It does not indicate how the computer was used because problems with numbers less than 156 may have consumed large amounts of machine time.

NUMBER	PROBLEM SPECIFICATION	AFFILIATION
156	Relativistic transformations	Physics
157	Deflection of a three-bay three-story frame	Civil Engineering
158	Test $2^{8191}-1$ for small factors	Computer
159	Influence coefficients for forced vibration of uniform bars	Civil Engineering
160	Boundary-value differential equations	Computer
161	Photon Spectrum matrix	Physics
162	Random walk	Chemistry
163	Iteration counter	Computer
164	Check point routine	Computer

III USE OF THE COMPUTER

A review of the operator's log shows that in the period between

May 16 and June 15, 1953, programs were put on the ILLIAC by 50 different individuals affiliated with 13 departments of the University.

For several months there have been two daily code checking periods of one hour each, one from 12-1 pm and one from 4-5 pm. The interval between February 16 and May 15, 1953 has been examined. During this time 1079 codes were checked in the code-check periods. Of these 1079, 1015 were limited to a maximum machine time of 10 minutes. The data are as follows:

ILLIAC TIME (Minutes)	NUMBER OF CODES	TOTAL TIME (Minutes)
1	115	115
2	184	368
3	181	543
4	148	592
5	75	375
6	77	462
7	84	588
8	64	512
9	39	351
10	48	480
	1015	4386

The average code check took 4.3 minutes. This time includes time for changing tapes, doing post mortem checks on codes and making entries in the operator's log.

With the aim of finding out more about coding errors and how to eliminate them a chart has been posted in the Computer Room. This chart lists the common errors made by coders and also the usual ways of finding them. Space is provided for "unusual" errors, and coders are being asked to make notations on the chart.

A description of the code checking routines in the ILLIAC library has been prepared and is available to coders. This 6-page report tells about the 10 checking routines, giving instructions on how to use them. Copies of

most of these routines are kept by the operator at the ILLIAC so that they may readily be used.

Table I shows the distribution of machine time for the interval May 16 through June 15, 1953:

TABLE I

	h m
Engineering 8-12	49:51
Engineering 12-12	42:22
Idle	3:59
R.A.R.	21:24
Leapfrog	36:26
E.D.C.	
Wheeler	20:35
Nash	:12
Clutterham	:34
King	1:19
Gregory	:28
Cobb	:43
Muller	:46
Others	1:29
Classes	31:59
Physics	49:15
C.S.L.	40:43
Civil Engr.	39:16
Psychology	5:33
Elect. Engr.	:34
Ins. Comm. Res.	1:29
Chemistry	2:59
Agricultural Econ.	4:09
Chem. Engr.	:19
Mathematics	1:20
Public Health (Psychology)	4:41
Demonstrations	:30
Total:	364:32

IV ERROR FREQUENCY AND ANALYSIS

The machine is normally used for "engineering" and maintenance between 8 AM and 12 N, and for a check of its performance between 5:00 PM

and 5:30 PM of each weekday. Since the periods between 8 in the morning and noon, together with certain other irregular periods like Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more instructive from an error analysis standpoint to look at the periods between noon and midnight of each weekday in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind a summary table has been prepared using the period between noon and midnight of each weekday. This table lists the running time when the machine was operating, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 5:00-5:30 period (when the machine is checked) if no errors are found, the time is given to the "running column". Each failure was considered to have terminated a running period and was followed by a repair period in preparing this Table. Since the leapfrog code is very probably our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented as Table II.

Table II shows a larger than normal number of errors during the month. Twenty-two of the fifty-one errors were associated with the punch so that twenty-nine errors may be considered to be associated with other parts of the machine. Because a great deal of work was put into the punch much of the normal running time for the machine is listed as repair time associated with the punch. The punch caused errors because of mechanical tolerances. At least temporarily it is necessary for us to operate the punch at about 20

characters per second instead of the usual 25 characters per second. Because such a large fraction of time during the month was spent with the punch, Table II does not have the significance that past reports have had in making an estimate of the error-frequency of the machine.

DATE	[illegible]	[illegible]	[illegible]	TYPES OF FAILURE	FAILURE [illegible]	[illegible]	[illegible]	[illegible]
9/19/53	10:51	150	3	(1) Filament failure in address [illegible]	[illegible]	(?)	[illegible]	[illegible]
				(2) Unknown	[illegible]			
				(3) Block feed error	[illegible]			
[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	1:00	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	(1) [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				(2) [illegible]	[illegible]			
[illegible]	[illegible]	[illegible]	[illegible]	(1) [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				(2) [illegible]	[illegible]			
[illegible]	[illegible]	[illegible]	[illegible]	(1) [illegible]	[illegible]	[illegible]	1:00	[illegible]
				(2) [illegible]	[illegible]			
[illegible]	[illegible]	[illegible]	[illegible]	(1) [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	(1) [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				(2) [illegible]	[illegible]			
[illegible]	[illegible]	[illegible]	[illegible]	(1) [illegible]	[illegible]	[illegible]	[illegible]	
9/29/53	[illegible]	[illegible]	1	(1) [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				(2) [illegible]	[illegible]			
				(3) [illegible]	[illegible]			
9/29/53	[illegible]	[illegible]	1	(1) [illegible]	[illegible]	[illegible]	[illegible]	
[illegible]/53	9:[illegible]	[illegible]	[illegible]	(1) [illegible]	[illegible]	[illegible]	[illegible]	
				(2) [illegible]	[illegible]			

DATE	RUNNING	REPAIRS	FAILURES DURING RUNNING TIME	TYPES OF FAILURES	WAS FAILURE FIXED?	WASTED	LEAPFROG	FAILURES OF LEAPFROG
6/2/53	9:04	2:56	7	(1) Leapfrog 0 → 1: 2^{-5} Add. 23S	No	:00	:18	2
				(2) Punch error	No			
				(3) Memory Chassis	Yes			
				(4) Punch error	No			
				(5)	No			
				(6) Memory Error pos 20 chassis changed	Yes			
				(7) Punch error due to 6SQ7 failure	Yes			
6/3/53	5:47	6:08	4	(1) Punch error	No	:05	:30	00
				(2) Adder Error	No			
				(3) Error unknown	No			
				(4) Punch error	No			
6/4/53	11:48	:07	1	(1) Chad chute clogged	Yes	:05	:44	0
6/5/53	9:57	2:01	1	(1) Error unknown	No	:02	1:07	0
6/8/53	11:02	:56	3	(1) Error unknown	No	:02	:27	0
				(2) Error unknown	No			
				(3) Memory position 14	Yes			
6/9/53	7:10	4:50	2	(1) Adder errors, 5 tubes changed	Yes	:00	:31	0
				(2) Add. generator tube failure	Yes			
6/10/53	11:42	:12	1	(1) Reader light burned out	Yes	:06	:48	0
6/11/53	9:22	2:38	5	(1) Error unknown	No	:00	[illegible]	1
				(2) Flew on OIL Tube 1	Yes			
				(3) Flew on OIL Tube 24	Yes			

DATE	RUNNING	REPAIRS	FAILURES DURING RUNNING TIME	TYPES OF FAILURES	WAS FAILURE FIXED?	WASTED	LEAPFROG	FAILURES OF LEAPFROG
6/11/53				(4) Error may be punch	No			
				(5) Fuzzy Punch Holes	No			
6/12/53	9:35	2:25	4	(1) Multiplication error	No	:00	1:02	2
				(2) Division error	No			
				(3) Printer error, tube failed	Yes			
				(4) Adder error	No			
6/15/53	11:32	:26	4	(1) Memory	Yes	:02	1:19	[illegible]
				(2) Punch error	No			
				(3) Fix. add 289 ops 2^{-15}	Yes			
				(4) Punch error	Yes			
	211:04	40:17	[illegible]		21-Yes [illegible]	[illegible]	13:01	[illegible]

V COMMENTS ON THE MACHINE

A. Memory

Four cathode ray tubes were removed from the memory during the month. All of these tubes were removed because of flaws. It is believed that some progressive change has occurred which is affecting the focus of the tubes and hence the number of flaws and RAR performance of the memory. Until recently it has been possible to state that the number of read-around failures at 80 was 0 or very, very few in number. During the last two weeks of operation of the machine the read-around has fallen so that there are frequently two or three errors at a read-around test of 70. Since there has been an irregularity in the types of failures it has not been possible simply to adjust the memory to increase the RAR. An examination will need to be made of some of the memory circuits in order to ascertain what has caused the change in the performance characteristics.

Because of small tube failures three memory chassis were changed during the month.

B. Input-Output

After the new high-speed punch mentioned in the last report was placed into operation a mechanical failure of a hardened steel part occurred which apparently started a series of punch errors. As a result of the mechanical failure certain adjustments were made in both punches which gave rise to errors which have been listed under the error analysis in the previous section. Although this was the largest single cause of errors in the machine, because the errors were intermittent and associated with the mechanical unit a considerable amount of time was spent in locating the

errors. It was finally necessary to slow down one of the punches about 20% until improvements could be made in the mechanical tolerances. While the type of error is now believed to be well understood, the difficulty has not yet been repaired and the punch is therefore operating with a speed of 20 characters per second instead of 25 characters per second.

C. General

As a result of a couple of occasional errors in the adder, several poorly soldered connections were found. It was necessary to change several tubes because of intermittent shorts. All together, 140 tubes have failed with a total machine time of 3,620 hours.

VI RESEARCH AND DEVELOPMENT (Supported in part by ONR Task 24)

A. Transistor Circuits

During the past month the response time of the MIT flipflop was measured using triggering pulses with rise times and durations of half a microsecond or less. The waveforms obtained from the output of the flipflop had about the same rise and fall times, and varied only slightly when various transistors were substituted in the flipflop circuit. It was also found that the positive supply voltage to the flipflop could be decreased by 50% from 45 to 22 1/2 volts, and satisfactory operation was still observed. The negative supply voltage could not be varied separately by this amount without causing failure of the circuit but the positive and negative voltages could be decreased simultaneously by half, without observing a failure.

B. Drum Circuits

During the first part of the month time was spent in further reducing noises from various sources which would affect the playback

amplifiers. The second part of the month consisted in measuring and reducing switching and recording transients. When first measured these transient times were about 1800 μseconds each. Taking every 8th word, the maximum that could be allowed is 1080 (the rest of the time is needed for computation). By suitable circuit changes the times are now 1000 μseconds.

The drum test unit has been built. It will contain all the necessary circuits to operate four channels of the drum plus the control tracks of the drum with circuits which simulate the operation of the ILLIAC. A drum test control (logical drawing M-508 and circuit drawing L-509) has been designed. This control with four pulsers, simulates those functions which would normally be performed by the ILLIAC if the drum were connected to it. A drum memory of 256 words of 8 bits each will initially be simulated. Single or successive recording, single or successive playback, or alternate recording and playback can be carried out at an address selected by 8 switches.

C. Memory Sensing Studies

Experiments with special sensing systems were carried out as indicated toward the close of last month. The comparison sensing system was tested more thoroughly and found to operate about as well as the ILLIAC system but not better in any significant sense. It has for that reason been set aside, at least for the moment.

VII CONSTRUCTION

Construction work has been carried out on the drum test unit and on the high speed punches.

VIII SEMINARS

MAGNETIC DRUM CONTROL CIRCUITS by J. E. Robertson
May 20, 1953

TROUBLE SHOOTING FOR ERRORS IN PROGRAMS by D. J. Wheeler
May 27, 1953

IX PERSONNEL

The personnel associated with the group and hence the contributors to this report are:

Brown, Caroline
Clutterham, D. R.
Cobb, Bessie, (1/2 time)
Ehrlich, George
House, Natalie R.
Huffman, W. Logan
Jones, Walter E
Kerkering, Thomas E.
King, Richard (1/2 time)
Kudlich, R. A. (1/2 time)
Lopeman, H, E.
Meagher, R E.
Michael, G. W.
Miller, Raymond E. (starting 7/1/53)
Muerle, John (started 6/16/53)
Muller, D. E.
Nash, J. P.
Newmark, N. M. (Chmn. Exec. Comm.)
Polivka, R. P.
Robertson, J. E.
Russell, Ramona
Shapin, Theodore Jr.
Stone, David E.
Taub, A. H. (1/2 time)
Wier, J. M.
Wheeler, D. J.

R. E. Meagher
R. E. Meagher

REM/nrh

UNIVERSITY OF ILLINOIS

GRADUATE COLLEGE

DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

June 16, 1953 - July 15, 1953

I MATHEMATICAL RESEARCH AND CODING (This is supported in part by ONR Task 30)

A set of brief descriptions of important library subroutines is being prepared. Each description gives only the information required by a person who wishes to use the subroutine.

The logical algebra subroutine (Library Code 81) has been rewritten to provide a new type of algebraic operation, two new types of control transfer, and new input and output orders. Some revision is still necessary. Dynamic logical design theory developed by I. S. Reed at M. I. T., has been modified so as to apply to ILLIAC logic. Work is progressing on a new type of three-valued logic which may be applicable to dynamic circuits.

During the past month the following new programs have been placed in the library. Codes 100 and 101 were written by Professor J. N. Snyder of the Physics Department.

93. Iteration Counter. 35 Words.

This program may be used to determine if a count in an unchecked routine is performed correctly or to determine the number of iterations in a cycle.

94. Post Mortem for Fractions and Their Locations. 31 Words.

A new version of Code 56, this program uses less storage and prints faster by suppressing the printing when a memory location contains zero.

95. Check Point Routine II. 57 words plus variables storage.

This is an improved modification of Code 83 which permits a programmer to choose seven ways of printing at check points and gives

him wide latitude in arranging his checking.

96. Floating Decimal Logarithm Auxiliary. 59 Words.

Arranged for use with Code 63, this auxiliary replaces the number in the floating accumulator by its natural logarithm.

97. Post Mortem for Integers and Their Locations. 38 Words.

This is a new version of Code 57 which is similar to Code 94.

98. Poisson's Equation, Liebmann-Frankel Method. 65 words plus grid and key word storage.

This code solves the two-dimensional Poisson equation for a closed region. For very simple boundaries the number of mesh points is limited to about 950.

99. Floating Decimal Cube Root Auxiliary. 41 Words.

Arranged for use with Code 63, this auxiliary replaces the number in the floating accumulator by its cube root.

100. Complete Linear Equation Solver. Entire Program.

This program, having solved up to 37 linear algebraic equations by the method of Code 47, will calculate residuals and furnish an improved set of answers when the results are read back in. The process can be repeated. Code 100 replaces Code 74 which is now obsolete.

101. Sequence of Random Numbers. 13 Words.

Using a starting value suggested by N. Metropolis of Los Alamos this routine constructs 38 binary-digit pseudo-random numbers by the process of squaring and extracting the middle digits. The programmer can choose his starting point in the sequence produced. After the first entry 6 of the 13 words can be dropped from the routine.

102. Floating Decimal Exponential Auxiliary. 25 Words.

This auxiliary, for use with Code 63, replaces the quantity

x in the floating accumulator by e^x.

II NEW PROBLEMS LISTED FOR THE MACHINE

The following list gives problem specifications for new problems which were tried during the month. It does not indicate how the computer was used because large amounts of machine time may have been consumed by problems with numbers less than 165.

NUMBER	PROBLEM SPECIFICATION	AFFILIATION
165	Cube root auxiliary	Computer
166	Differential pair cross section	Physics
167	Sequence of definite integrals	Math
168	Eigenvalues of 8 x 8 matrix	Computer
169	Set of second order simultaneous differential equations	Structural Engr.
170	Radio wave propagation	Electrical Engr.
171	Logarithm auxiliary	Computer
172	Phi coefficients	Bureau Educational Research
173	Triplet proton-neutron scattering	Physics
174	Two-point boundary value problem	Computer
175	Logical algebra subroutine	Computer
176	Exponential auxiliary	Computer
177	Pattern analysis	Psychology
178	Matrix multiplication auxiliary	Computer
179	Letter printing	Computer
180	Simultaneous linear equations	Psychology
181	Milne's method	Computer
182	Compute $A^{1/p}$	Computer
183	Set of 3^{rd} order differential equations	Computer

Table I shows the distribution of machine time for the interval June 16 through July 15, 1953:

TABLE I

	h m
Engineering 8-12	39:08
Engineering 12-12	35:37
Idle	:33
Read-around Tests	17:31
Leapfrog	56:54
Digital Computer Laboratory	
Wheeler	19:19
Nash	:05
Polivka	:47
Golub	:58
King	:59
Gregory	:45
Cobb	1:26
Muller	3:14
Others	1:11
Classes	1:24
Physics	67:59
CSL (U.S. D.A. 11-022-Ord. 721)	38:20
Structural Engineering	35:50
Structural Engineering (AF-24994)[*]	3:16
Psychology	4:28
Psychology (AF-25726A)[*]	3:07
Special	:05
Electrical Engineering	3:30
Chemistry	:44
Agricultural Economics	7:55
Chemical Engineering	17:11
Mathematics	1:49
Psychology (U.S. Public Health 3M-9020-C3)	12:01
Education	4:40
Demonstrations	:53
Total:	381:39

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[*] The recording of time for these specific contract numbers did not start until July 1, 1953. Some time on these may be listed elsewhere during the preceding two weeks.

III ERROR FREQUENCY AND ANALYSIS

The machine is normally used for "engineering" and maintenance between 8 AM and 12 N, and for a check of its performance between 5:00 PM and 5:30 PM of each weekday. Since the periods between 8 in the morning and noon, together with certain other irregular periods like Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more instructive from an error analysis standpoint to look at the periods between noon and midnight of each weekday in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind a summary table has been prepared using the period between noon and midnight of each weekday. This table lists the running time when the machine was operating, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 5:00-5:30 period (when the machine is checked) if no errors are found, the time is given to the "running column". Each failure was considered to have terminated a running period and was followed by a repair period in preparing this Table. Since the leapfrog code is very probably our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented as Table II.

DATE	RUNNING	REPAIRS	DURING RUNNING TIME	TYPES OF FAILURES	WASTED	LEAPFROG	FAILURES OF LEAPFROG
6/16/53	10:41	1:18	2	(1) L for a 0 in punched data	:01	:43	0
				(2) Reader error. Light from one hole affected another hole			
6/17/53	11:33	:26	4	(1) 1 ⟶ 0 position 20 address 1F6, memory error	:01	:31	[illegible]
				(2) Punching error			
				(3) Punching error			
				(4) Hung up on 0 left shift - reason unknown			
6/18/53	10:01	1:59	9	(1) 0 ⟶ 1 position 24 address 000	:00	1:47	[illegible]
				(2) Unknown			
				(3) Probably punching error			
				(4) 0 ⟶ 1 address 087 position 24			
				(5) Hung up on 0 left shift			
				(6) Unknown			
				(7) Reason unknown			
				(8) Reason unknown			
				(9) Punching error			
6/19/53	8:36	3:20	2	(1) 0 ⟶ 1 position 5 address 203	:04	[illegible]	[illegible]
				(2) Multiplication failure 1 ⟶ 0 position 0 address 174			
6/22/53	11:31	:28	1	(1) 0 ⟶ 1 position 32 address [illegible]	:01	[illegible]	

DATE	RUNNING	REPAIRS	FAILURES DURING RUNNING TIME	TYPES OF FAILURES	WASTED	LEAPFROG	FAILURES OF LEAPFROG
6/23/53	11:04	:54	2	(1) Complete failure of position 4 to store (2) Stopped on an S3 order on r.h. side	:02	:46	0
6/24/53	12:00	:00	0		:00	1:09	0
6/25/53	10:19	1:41	1	(1) 0 → 1 position 19 address 03L	:00	:48	1
6/26/53	8:11	3:47	2	(1) Even order gate 2^{-0} tube (2) 0 → 1 address 01L pos. 7	:02	:54	1
6/29/53	7:28	4:30	4	(1) Morning engineering not finished (2) Comparison failure (leapfrog) (3) Comparison failure (leapfrog) (4) Flaw position 37 address 05J	:02	1:35	4
6/30/53	11:33	:25	2	(1) Reader out of step one character (2) Reason unknown	:02	:30	0
7/1/53	11:27	:31	2	(1) Transient from D.C. turn on in Room 157 (2) D.C. Power Supply Transient	:02	:32	0
7/2/53	11:42	:12	1	(1) 0 → 1 position 26 address 21K	:06	:50	1
7/3/53				HOLIDAY			
7/6/53	10:13	1:47	4	(1) Reader out of step (2) Counting index stopped counting. Reason unknown (3) 300V power supply reg. amp. failed (4) 0 → 1 position 8 (leapfrog)	:00	1:11	1

DATE	RUNNING	REPAIRS	DURING RUNNING TIME	TYPES OF FAILURES	WASTED	LEAPFROG	FAILURES OF LEAPFROG
7/7/53	11:41	:19	3	(1) 0 ⟶ 1 position 26, address 3LF	:00	1:02	3
				(2) 0 ⟶ 1 position 10 add. 000			
				(3) 0 ⟶ 1 position 9 add. OSF			
7/8/53	1:32	10:28	1	(1) Failure of reader to stop	:00	0	0
7/9/53	8:33	3:22	5	(1) Did not obey a 20 order, black switch suspected	:05	1:12	0
				(2) Program stopped, reason unknown			
				(3) Reader read "N" as "8"			
				(4) Program failed after 40 minutes, reason unknown			
				(5) Program stopped			
7/10/53	9:11	2:47	3	(1) Reader stopping trouble	:02	1:27	1
				(2) 0 ⟶ 1 pos. 5 add. 000			
				(3) Multiplication check failure			
7/13/53	9:56	2:04	5	(1) Hung up in DOI	:00	:39	1
				(2) As above			
				(3) Shorted tube in dispatch counter			
				(4) Burned out Fil V5 Dec. chassis			
				(5) Carry amp. tube shorted			
7/14/53	11:39	:17	1	(1) Punch error. Not punching chad clear of holes	:04	:27	0
7/15/53	11:57	:03	1	(1) Output tape failed to advance. Chad chute full.	:00	:51	0
TOTALS	210:48	40:38	55		:34	20:23	21

IV COMMENTS ON THE MACHINE

It may be noted that the number of machine errors during the month continues to be higher than several months ago. From the table it can be seen that 7 errors are due to the punch, 6 errors are due to the reader, 15 errors are due to the memory (13 of these are 0 to 1 failures), and 16 are listed as due to unknown causes. The remaining errors are of a miscellaneous nature.

The memory errors occur most frequently at the upper corners, a fact which should be helpful in indicating the cause.

V RESEARCH AND DEVELOPMENT (Supported in part by ONR Task 24)

A. Drum Circuits

Measurements were made of the amount by which the gain of a playback amplifier could vary and still operate correctly on playback signals occuring at both the maximum and minimum frequencies that would be encountered. At a maximum density equivalent to 64 words around one track, the gain could vary only ±10%. Since this figure applies to the complete playback system of head, pre-amplifier and main amplifier and any of 50 heads and pre-amplifiers must operate with a given main amplifier, it is felt this tolerance is not large enough.

The effect that is the largest factor in the small gain tolerance is the decrease in amplitude of playback signal at high digit densities. By allowing 32 words around a track, the digit density is reduced to 52 bits per inch. The gain tolerance was measured to be ±40% for this maximum density.

Since there are reports of successful recordings at digit densities at least as high as 150 per inch our lower limit is evidently set by the particular head structure and recording surface we are using.

It is planned to proceed on the assumption that 32 words will be stored per track. This involves no changes in the control circuits other than that the word counter now needs to count only to 32 instead of 64.

"Debugging" of the control circuits in the control circuit test rack was started. Control track leads were run to the rack from the drum.

B. Transistor Circuits

During this month, an analysis was made of the tolerance characteristics of the two transistor flipflop with respect to the existence of two non-saturating stable states. This analysis indicates that the present circuit, or any minor modification of it, will not meet tolerance requirements comparable to those which our present vacuum tube circuits must meet.

If only components external to the transistor vary, such as resistors and power supply voltages, then only the worst possible combination of ten per cent change in every component will result in the loss of one of the non-saturating stable states. On the other hand, if the external components are held constant and the transistor parameters are varied, one of these states is lost with variations appreciably smaller than those allowed by the manufacturer. Thus this circuit could not be expected to operate with all of the transistors which the

manufacturer considers acceptable.

Major changes in the circuit, such as the addition of crystal diodes to change the shape of the input impedance curve, will be necessary if the circuit is to operate with reasonable variation in transistors. There is no certainty that such changes will make the circuit satisfactory.

C. Cathode Ray Tube Output

A cathode ray tube output circuit was designed during the month and is in the process of being built. This circuit is designed to attach to the standard machine output. It is asynchronous in nature. The cathode ray tube output order will successively take 4 sexadecimal digits from the 2^0, 2^{-1}, 2^{-2}, 2^{-3} R_1 positions on either the 82 or 92 orders and place them in a buffer register and then allow the machine to proceed. The scope is brightened up after the machine has been released. The length of this bright-up pulse is set by a pulser. It has been ascertained that a 250 μs bright-up pulse is satisfactory. This, along with the output shifting time, indicates that 1400 spots per second (as an upper limit) may be plotted with this output.

VI CONSTRUCTION

1. Punch output table,
2. Punch output chassis assembled but not wired,
3. Two chassis for cathode ray tube output assembled and partly wired (Drawing No. L-515 and L-514),
4. Regulator for ILLIAC address generator (Drawing No. S-516),
5. Checked 500 815 tubes,

6. Built and installed new output switch for ILLIAC,
7. -2000v power supply for cathode ray tube output (Drawing No. M-519),
8. Cathode ray tube bleeder and circuits for cathode ray tube output (Drawing No. S-517).

VII PERSONNEL

The personnel associated with the group and hence the contributors to this report are:

Brown, Mrs. Caroline
Cobb, Miss Bessie (1/2 time)
Gregory, R. T. (1/4 time)
Golub, Gene (1/2 time)
Ehrlich, George
House, Mrs. Natalie R.
Huffman, W. L.
Jones, W. E.
Kerkering, T. E.
King, Richard (1/2 time)
Kudlich, R. A. (1/2 time)
Lopeman, H. E.
Meagher, R. E.
Michael, G. W.
Miller, R. E. (1/2 time)
Muerle, J. L. (1/2 time)
Muller, D. E.
Nash, J. P.
Polivka, R. P. (1/2 time)
Robertson, J. E.
Russell, Miss Ramona
Shapin, Theodore Jr.
Stone, D. E.
Wier, J. M.

David R. Clutterham, having received his Ph.D., has joined the research staff of Consolidated Vultee Aircraft at Fort Worth.

The work of the group is under the administration of an Executive Committee with the following members: N. M. Newmark, Chairman, D. E. Muller, J. P. Nash, J. E. Robertson, A. H. Taub and R. E. Meagher.

R.E. Meagher
R. E. Meagher

REM/nrh
7/22/53

UNIVERSITY OF ILLINOIS

GRADUATE COLLEGE

DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS
REPORT

July 16, 1953 - August 15, 1953

I MATHEMATICAL RESEARCH AND CODING (This is supported in part by ONR Task 30)

During the past month the following new programs have been placed in the library. Code 107 was written by Dr. R. M. Brown of the Control Systems Laboratory.

103. Order Pairs Post Mortem. 32 words.

This is an improved version of Code 59 which it replaces.

104. Matrix Multiplication Auxiliary. 26 words with punch out; 21 words without punch out.

This code, used with Floating Decimal Code 63, accepts matrix elements in floating decimal form.

105. Integral Root $A^{1/p}$. 24 words.

This code, given A and the positive integer p, computes $A^{1/p}$ by Newton's method.

106. Fractional Power. 18 words.

Given $2^{-7} \leq A \leq 1 - 2^{-36}$ and $0 < x < 1$, this code uses the binomial expansion to determine A^x.

107. Arithmetic Programming Code. 254 words.

This interpretive routine is designed to program and to punch out the sequence of orders necessary to perform numerically any set of mathematical operations expressable with machine orders or with certain types of library subroutines. The programmer prepares his problem in a form very similar to an oral reading of the function equation, giving orders

for parentheses, etc. The program is especially biased toward simple and efficient coding of routines for evaluating functions like

$F=a-b+cd^3+ (e+f)/(g+h)+ \sin (j+k)^2.$

108. Shifting Sum Check. 11 words.

The previous sum check (Code 76) has the disadvantage that if the number of errors in digit position 2^{-m} is divisible by 2^{m+1}, and if the errors are in the same direction, then they will not be detected. By shifting before summing Code 108 avoids this difficulty.

~~109~~ 110. Cathode Ray Tube Fractional Post Mortem. 63 words.

This code displays on the cathode ray tube output selected sets of 10 consecutive signed 12-place decimal fractions. In action and layout it is very much like Code 94.

II NEW PROBLEMS LISTED FOR THE MACHINE

The following list gives problem specifications for new problems which were tried during the month. It does not indicate how the computer was used because large amounts of machine time may have been consumed by problems with numbers less than 184.

NUMBER	PROBLEM SPECIFICATION	AFFILIATION
184	Phi coefficients	Psychology
185	Pair production	Physics
186	Analysis of soil productivity data	Agronomy
187	Simultaneous equation floating auxiliary	Computer
188	Phi coefficients	Psychology
189	Principal components	Inst. Juv. Research
190	Arctangent floating auxiliary	Computer
191	Ranking of factor scores	Inst. Juv. Research
192	Dynamic buckling of rings	Structural Engr.
193	Matrix multiplication	Inst. Juv. Research
194	Integrate reaction equations	Physics
195	Compute fractional powers	Computer
196	Compute stresses in cylinders	Computer
197	Set of differential equations	Physics
198	Compute correlations	Inst. Comm. Research

Table I shows the distribution of machine time for the interval July 16 through August 7, 1953:

TABLE I

	h m
Engineering 8-12	24:55
Engineering 12-12	35:03
Leapfrog	28:40
Read-around Tests	15:26
Idle	:52
Digital Computer Lab	
Wheeler	66:48
Nash	2:58
Golub	2:06
Polivka	2:03
King	1:18
Cobb	1:08
Muller	1:06
Robertson	:01
Others	4:06
Physics	77:31
CSL (U.S.D.A. 11-022 ORD. 721)	31:04
Structural Research	29:18
Psychology (AF 25726A)	21:28
Structural Research (NOBS 62250)	18:57
Agronomy	14:33
Electrical Engineering	12:11
Structural Research (AF 24994)	6:17
Psychology	4:12
Psychology (U.S. Pub. Health 3M-9020-C3)	4:04
Institute for Juvenile Research	3:51
Chemistry	:48
Math Statistics	:43
Chemical Engineering	:26
Demonstrations	:20
Total:	412:53

III ERROR FREQUENCY AND ANALYSIS

The machine is normally used for "engineering" and maintenance between 8 AM and 12 N, and for a check of its performance between 5:00 PM and 5:30 PM of each weekday. Since the periods between 8 in the morning and noon, together with certain other irregular periods like Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more instructive from an error analysis standpoint to look at the periods between noon and midnight of each weekday in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind a summary table has been prepared using the period between noon and midnight of each weekday. This table lists the running time when the machine was operating, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 5:00-5:30 period [illegible] [illegible] [illegible] [illegible] leapfrog code is very probably our mos[illegible] length of time which it has been used on the machine [illegible] together with the number of errors associated with [illegible] [illegible]

DATE	RUNNING OK	REPAIRS	DURING OK TIME	TYPES OF FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	OF LEAPFROG
7/16/53	10:32	1:26	7	(1) Testing black switch (2) Testing black switch (3) Testing black switch (4) Unknown (5) Black switch (6) Leapfrog, reason unknown (7) Leapfrog, reason unknown	:02	1:07	2
7/17/53	5:21	6:36	2	(1) Code 566 started printing 0's. Black switch suspected (2) Black switch	:03	:00	0
7/20/53	7:01	4:57	4	(1) Memory failure (2) Leapfrog 0 → 1 pos 10 (3) Leapfrog pos 12 (4) Leapfrog Division failure	:02	3:09	3
7/21/53	11:42	:18	2	(1) Black switch (2) Checking reader	:00	:00	0
7/22/53	11:58	:00	0		:02	:25	0
7/23/53	11:58	:00	0		:02	:22	0
7/24/53	11:57	:03	1	(1) Chad chute clogged	:00	:37	0
7/27/53	6:16	5:44	4	(1) Leapfrog Input-output (2) Leapfrog unknown (3) Reader trouble (4) Stopped on 50 order	:00	1:40	2

DATE	RUNNING OK	REPAIRS	FAILURES DURING OK TIME	TYPES OF FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES OF LEAPFBOG
7/28/53	10:32	1:24	3	(1) Input trouble	:04	1:51	0
				(2) Reader error			
				(3) Gear on punch came loose			
7/29/53	9:56	2:00	3	(1) Leapfrog 1 → 0 pos 9. Multiplication failure	:04	1:08	1
				(2) Reader trouble			
				(3) Gear on punch came loose			
7/30/53	9:01	2:59	1	(1) Leapfrog 0 → 1 pos 29 1 → 0 pos 14	:00	1:01	1
7/31/53	11:59	:00	0		:01	:57	0
8/3/53	11:19	:41	2	(1) Reader trouble	:00	:38	0
				(2) Reader trouble			
8/4/53	7:29	4:29	2	(1) Possibly pos 36	:02	:58	2
				(2) Leapfrog division test. Shorted tube			
8/5/53	12:00	:00	0		:00	:25	0
8/6/53	12:00	:00	0		:00	:42	0
8/7/53	12:00	:00	0		:00	:22	0
Totals	173.01	30.37	31		:22	15:42	11

IV COMMENTS ON THE MACHINE

The ILLIAC was "officially" shut down at the close of the day, August 7, and will be down for about five weeks while new covers are installed. However, despite the loss of a week in the July 16-August 15 period, it will be noted that the total machine time was more than 30 hours greater than for the June 16-July 15 period. This was because of overtime running to clear up the work backlog before the shut-down.

The error analysis, for purposes of simplicity and uniform comparison, is always made for the 12-hour time interval between noon and midnight so that overtime running does not show. It will be noted that on August 5, 6 and 7 there were 3 days giving 36 successive error-free running hours. The record is actually much better than that. From the time of the shorted tube on August 4 until the machine was actually turned off on the morning of August 9 it was run 106 hours. In this 106-hour period only one known error occurred.

There seems to be a good reason for this record performance. On August 3 there ended a systematic check, which had taken about 6 weeks, of all of the tubes not in the adder or pluggable memory circuits. In this check 583 tubes were replaced. (The shorted tube found August 4 had been checked and put back as good.) Table III shows the results. It is now planned to test tubes in a periodic way so that all tubes will be tested about twice a year, or about every 2000 hours of running time.

TABLE III. TUBE TEST RESULTS

TUBE TYPE	TUBE COMPLEMENT OF COMPUTER	NUMBER OF TUBES CHECKED	TUBES REPLACED	
			NUMBER	PERCENT
1P42	1	1		
2C51	290	207	12	5.8
3E29	1			
3KP1	40			
5UP1	2			
6AG7	6	4		
6AK5	109	20	4	20.0
6AL5	211	50		
6AQ5	50	10	3	30.0
6AS7G	12	12		
6AU6	40			
6BQ7	72	15	2	13.3
6J6	1486	1003	288	28.7
12AT7	2	2		
12AU7	50	10		
12AX7	17	17	9	52.9
5583 (Gas Phototubes)	8			
5687	373	372	265	71.2
#44 Pilot Lamp	2			
Proj. Lamp	1			
OB 2	1			
Totals:	2774	1723	583	33.8

[illegible]

[illegible]		[illegible]	[illegible]	[illegible]
[illegible]	[illegible]			
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

V RESEARCH AND DEVELOPMENT (This is supported in part by ONR Task 24)

A. Drum Circuits.

The necessary control tracks have been recorded. These supply one pulse per revolution, one pulse per word, and one pulse per digit. The same signals can be used with the full 6400 word memory as well as with the test unit.

The word counter, coincidence gating control, record gating circuits and playback gating circuits are now working. Several circuits associated with the record and playback amplifiers have yet to be made to work.

B. Tape Comparison Unit.

The logical design for a tape comparer using two photoelectric readers has been completed, as has the design of the circuits for the comparison unit. The design of the control circuits is not yet complete.

C. Cathode Ray Tube Output.

Described briefly in last month's report, this unit is now operating. It uses information similar to that given to the punch, and both 82 and 92 output orders may be used. Sixteen binary digits furnish the coordinate information, the first 8 giving X and the second eight giving Y. The beam is then turned on at the location defined. At its present location in the memory laboratory about 50 feet from the computer the maximum output speed is about 1000 points per second. This speed can be nearly doubled when the unit is moved into the computer room. Tests indicate that a 50 microsecond exposure time is sufficient for satisfactory photographs with the P7 phosphor now in use. A P11 phosphor will probably be used later.

D. Static Memory.

The design for an experimental static memory with faster read out time than the Williams memory but with no fast read in time is nearly complete. This system will employ a flying spot tube for reading into and out of sheets of film. The film sheets will be prepared by a comparatively slow process using the flying spot tube, and in reading out the beam will be deflected to appropriate locations on the film. With proper arrangement it is believed that as many as 4,096 spots can be stored on the film sheet (or slide). The address generator will be stabilized by using two monitor tubes with masks as size references. A memory of this kind will not be flexible like a Williams memory but it has many uses. For example, if it is practicable the entire library of subroutines could be stored permanently and made quickly available. Words with changing parts and temporary storage would, of course, have to be stored in the dynamic memory.

E. Transistor Circuits

In the last month two modifications of the two-transistor flipflop have been studied from the standpoint of d-c tolerance characteristics. The first modification, designed to make the emitter "peak voltage point" more positive and to increase the negative resistance for small positive emitter currents, requires an additional supply voltage, resistor and crystal diode in the base circuit. The second modification is similar to the first but requires an extra diode to move the "peak voltage point" near zero. Analysis of these circuits has not been completed, but

present results indicate that the first modification will not have the desired tolerance characteristics.

The open-emitter d-c collector resistance of 65 type 1698 transistors was measured. Values were appreciably larger than those which were expected or the basis of the manufacturer's advance data sheet.

VI CONSTRUCTION

1. Tape punch control chassis built and installed in punch output table (Drawing M-460).

2. Cables for punch and CRT output installed.

3. Chassis for second CRT output built.

4. Checked 800 type 6BQ7A tubes.

VII PERSONNEL

The personnel associated with the group and hence the contributors to this report are:

Brown, Mrs. Caroline
Cobb, Miss Bessie (1/2 time)
Golub, Gene (1/2 time)
Ehrlich, George
House, Mrs. Natalie R.
Huffman, W. L.
Jones, W. E.
Kerkering, T. E.
King, Richard (1/2 time)
Kudlich, R. A. (1/2 time)
Lopeman, H. E.
Meagher, R. E.
Michael, G. W.
Miller, R. E. (1/2 time)
Muerle, J. L. (1/2 time)
Muller, D. E.
Nash, J. P.
Polivka, R. P. (1/2 time)
Robertson, J. E.
Russell, Miss Ramona
Shapin, Theodore, Jr.
Stone, D. E.
Wier, J. M.

On August 10th Miss Cobb terminated her work at the laboratory.

The work of the group is under the administration of an Executive Committee with the following members: N. M. Newmark, Chairman, D. E. Muller, J. P. Nash, J. E. Robertson, A. H. Taub and R. E. Meagher.

J P Nash

J. P. Nash

JPN/nrh

8/19/53

UNIVERSITY OF ILLINOIS
GRADUATE COLLEGE
DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

August 16, 1953 - September 30, 1953

I MATHEMATICAL RESEARCH AND CODING. (This is supported in part by ONR Task 30)

The Illiac has been shut down during the entire period covered by this report and therefore, since all library codes must be machine tested, no new programs have been placed in the library since the last report.

Several new programs have been written and will be tested as soon as the Illiac is operating on October 5th. Among these are the solution of a system of differential equations by Milne's method and matrix inversion by making use of the eigenvalue program (Library Code #42). This is an interim method for matrix inversion and will be replaced later by a more compact program. A program for solving second order differential equations with two point boundary conditions has also been prepared and is ready to be tested. Programs for aiding in the use of the oscilloscope output through subroutines which plot axes, sequences of points, and letters and figures have been outlined and are nearly ready for testing.

One change in the Order Code has necessitated an examination of the library subroutines. This is the modification of the divide order which causes the Illiac to stop if the division is improper. In a few library routines improper divisions have been made use of or cause no trouble, and these will have to be modified. For example, the simultaneous equations program has a place where the division of 0 by 0 may occur. This caused no difficulty before. Most library subroutines

are unaffected by the change in the divide order and some of them are improved. The Illiac will now stop if the user of the square root subroutine tries to extract the square root of a negative number.

II CODING MANUAL

Members of the staff of the laboratory have now finished drafts of 12 chapters of a 14 chapter coding manual being written to aid persons in the University in learning how to use the Illiac. Ten of these chapters have been duplicated and distributed within the laboratory for comment, and a few of them are being used as supplementary material in Mathematics 385, the first coding course.

III CHANGES IN ILLIAC

The machine was shut down at the close of the day on August 7th. Since that time a new set of covers was installed on the machine and certain changes have been made in the circuits which increase the machine speed and add new orders.

The new covers which have been installed are the covers which were originally ordered for the Illiac, but which were not finished before September 1952 when the machine was put into operation. The new covers have been put on the machine principally because they make it easy to get into the machine. The temporary doors were fastened with a large number of screws; the new ones are hinged. The doors can be easily removed if it is desirable and the machine presents a better appearance.

One change in the circuits within the machine involves the addition of the "orange gate". This allows a "straight down" shift from

R^1 to R_1 of the accumulator (A register) and makes the former addition sequence of shifting first right and then left unnecessary. The resulting saving in time reduces the addition order time by one memory period. Including memory access for the addend, the addition order time is now three memory periods (of 19 microseconds each) giving an addition order time of 57 microseconds. In order to allow for getting the addition order from the memory the addition order time in a code would be $4 \times 19 = 76$ microseconds. The actual orange gate tubes in RI were already in the machine but needed to be appropriately wired. Numerous other control changes were necessary, however, to put the orange gate operation into effect.

Other changes have been made in the control which extend the order code by adding nine new multiplication orders, bringing the total to twelve, and by adding a special series of addition orders. The multiplication orders now have the same variations as the addition orders. The new special series of addition orders called F and K orders are similar to L and S orders respectively but differ from the L and S orders by 2^{-39}. In order to carry out correct arithmetic 2^{-39} has been automatically "added" under certain conditions with L and S orders. The F and K orders do not add 2^{-39} when the L and S orders do, and the F and K orders do add 2^{-39} when the L and S orders do not. An F5n order adds 2^{-39} to a positive number at n and puts the result in the accumulator. Before the F5 order was available this would have taken two orders.

A further circuit change makes the machine stop on an improper

division.

A three page description of the new orders is available.

The machine will be available for regular use on October 5th.

IV TAPE PREPARATION FACILITIES

A number of additional pieces of Teletype equipment which have been on order for nine months have been received. These will very considerably increase the tape preparation facilities of the laboratory. The new units are:

2 Reperforators,
3 Transmitter-Distributors,
2 Keyboard Punches,
1 Page Printer.

The punches and the page printer need to be altered to work properly from our sexadecimal code. It has been found possible to separate the "figures shift" and "space" functions which were formally obtained only together. This changes the figures shift and letters shift characters and adds several new extra features including two delay characters which are desirable for even margins on the page. This will affect those codes, written in the past, which use letters. The tape code for the new function characters is:

TAPE HOLES	FUNCTION
00.000	Space
0 . 0	Carriage Return and Line Feed
0 .0	Letters Shift
00. 00	Figures Shift
00.	Delay
0 .	Delay

V AUXILIARY MAGNETIC MEMORY. (This is supported in part by ONR Task 24)

Using the test circuits and 4 channels of the magnetic drum, it has been possible to transfer 40 digit words from a 40 digit register to the drum at any location on the 4 channels, and it has also been possible to make the reverse transfer. The circuits have been operating well and correct operation of these circuits have been obtained for periods of 30 minutes. At the present time an experimental study is being made of the tolerances of the voltages associated with reading and recording and of the timing of the pulses which are used for coincidence and other reasons. If the circuits for the drum prove to be entirely satisfactory, it will be necessary to construct 200 amplifiers and to build a final framework and cabinet for the circuits. All of the control circuits which are now in use may be used directly on the final assembly.

Information is currently being stored at a density of thirty-two 44 digit spaces per circumference as compared to sixty-four 44 digit spaces as the drum was originally planned some time ago. This change has been necessitated because of the frequency response of the recording heads. The tolerance work on the drum should be finished by October 15th.

VI RESEARCH AND DEVELOPMENT. (This is supported in part by ONR Task 24).

A study has been made of a high speed output using an oscilloscope display and a study has been made which suggests a scheme for core memories which would allow larger safety factors for a given type of core than those which have been designed in the past. Brief discussions of these items are presented here.

A. High Speed Output

An oscilloscope output for the machine has been built. This output has been described briefly in the two preceding monthly reports and is arranged so that the leftmost 16 binary digits from the accumulator can be used to supply the Y and X coordinate information for brightening up one spot on an oscilloscope tube. The first 8 digits supply the Y coordinate and the second 8 digits supply the X coordinate. Using this oscilloscope output, it is possible to form characters of many shapes with the Illiac and display them by means of a succession of spots. With the addition of more equipment it would be possible to display a complete character on the oscilloscope face for each output order from the Illiac.

About 350 tubes and 300 magnetic cores would have to be added to the oscilloscope output before it would be possible to display an entire character for each output. The output speed has been estimated at from 500 to 1000 characters per second depending upon the amount of detail which would need to be allowed for each character. A complete system of this type will be described in an internal report.

B. Core Memories

The desire for larger high speed memories initiated a number of experiments on Williams-tube-like systems. None of these produced results which would indicate large possible improvements in circuits. Improvements in tubes, of course, would be of great benefit. This laboratory has a set of 60 cathode ray tubes type C73621 on order from RCA.

These tubes, made on a developmental basis are expected to be considerably better than the selected 3KP1 tubes now in use.

Several preliminary considerations of core memories have been made and information has been received from other laboratories on core work, notably the work at M.I.T., and at the R.C.A. Princeton Laboratories.

It now appears that a significant improvement could be made by using magnetic switches in a more generous fashion with a different selection scheme.

The scheme can be described in this way: If one considers the present Illiac memory of 1024 numbers of 40 binary digits, the corresponding core memory which is usually proposed has 32 selection wires vertically and 32 selection wires horizontally. Many of the cores then need to discriminate between a one wire excitation (should not produce a core output signal) and a two wire excitation (should produce a core output signal). If instead a switch matrix of 1024 cores is used the one selected core could be used to excite 40 cores of the main memory. The 1024 switch cores would need to have "high" quality rectangular hysteresis loops, but the 40960 cores could have relatively poorer characteristics. Only a single selection wire, a "Z axis" would be required for a core signal. Variations of this could be used with either a dynamic or a static (for subroutines) memory. Reports describing these will be written if further study does not find a disadvantage.

VII SEMINARS

September 23, 1953
Subsidiary Conditions Applied to Switching Functions
By David E. Muller

September 30, 1953

Relative Rates of Output and Output Devices for Digital Computers

By Joseph M. Wier

VIII PERSONNEL

The personnel associated with the group and hence the contributors to this report are:

Brown, Mrs. Carolyn
Ehrlich, George
Fishel, Jerome (1/2 time - starting 9/1/53)
Gill, Stanley (Visiting Assistant Professor of Math - starting 9/16/53)
Golub, Gene (1/2 time)
Gregory, R. T. (1/4 time)
Guroff, Gordon (Student Assistant)
House, Mrs. Natalie R.
Huffman, W. L.
Jones, W. E.
Kerkering, T. E.
Kudlich, R. A. (RCA Fellow - starting 9/16/53)
Lopeman, H. E.
Meagher, R. E.
Michael, G. W.
Miller, R. E. (1/2 time)
Muerle, J. L. (1/2 time)
Muller, D. E.
Nash, J. P.
Newmark, N. M. (Chairman, Executive Committee)
Polivka, R. P. (1/2 time)
Robertson, J. E.
Russell, Miss Ramona
Seinfeld, Robert (Student Assistant)
Seshu, Mrs. Lily (1/2 time - starting 9/16/53)
Shapin, Theodore Jr.
Stephens, Allen
Taub, A. H. (1/2 time)
Wier, J. M.

The work of the group is under the administration of an Executive Committee with the following members: N. M. Newmark, Chairman,

S. Gill, D. E. Muller, J. P. Nash, J. E. Robertson, A. H. Taub and R. E. Meagher.

R. E. Meagher.

REM/nrh

UNIVERSITY OF ILLINOIS
GRADUATE COLLEGE
DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

October 1, 1953 - October 31, 1953

I MATHEMATICAL RESEARCH AND CODING (This work is supported in part by ONR Task 30)

Polynomial Approximations. Testing is nearly complete of a program for preparing on the Illiac the shortest polynomial approximation to kf(ax + b) over the range $c \leq x \leq d$ with maximum error $\leq \epsilon$, given sufficient terms of the Taylor series expansion of f(x). This program will lead to economy in several future programs which would otherwise use inefficient approximations because of the difficulty in computing better ones.

Floating Point Auxiliary. Intended primarily for use in Mathematics 385, a tape is being prepared which will contain Floating Decimal Code 65 and all of the auxiliaries. Thus far sine and cosine and a new exponential auxiliary have been written. These have been tested without final values for the coefficients in the polynomial approximation so that the above mentioned polynomial approximation code can be used for the final computations.

In addition to the usual auxiliaries the tape will also contain a subroutine (which they use) for converting numbers from floating to nonfloating form. An input routine has been written to simplify handling constants when a floating point is used. This code, which is now operating, allows constants to be read in the same way as Code 90. For example, 84N + 6957 - 02 will cause 0.6957×10^{-2} to be added to the floating accumulator.

The final long tape will make it easier for students in Mathematics 385 to learn to write short routines using interpretive orders.

Dynamic Switching Circuits. Additional work has been done in the theory of dynamic asynchronous switching circuits. Transmission of information using such circuits has been studied.

Polynomial Minimization. An internal report on the minimization of polynomials subject to subsidiary conditions has been written and an Illiac program for carrying out this process has been prepared.

Machine Timing Code. A program which will simplify determination of speeds of basic machine operations such as the memory period and the arithmetic and shift orders is being prepared.

Boundary Value Differential Equation. A code using the floating decimal program is being written for solving second order differential equations with two point boundary conditions.

Automatic Eigenvalues and Eigenvectors. This code, which is now working, requires only that the coder present to the Illiac the matrix to be analyzed and two parameters, the order n of the symmetric matrix and the number g of decimal digits to be printed in the results.

Matrix Inversion. The matrix inversion code mentioned in the last report is now working. It uses the eigenvalue-eigenvector code and can invert symmetric matrices up to order 23, taking 14 1/2 minutes for this case. Since the eigenvalues are obtained, we have a measure s/ℓ of the matrix conditioning where s and ℓ are the smallest and largest eigenvalues. The quantity $|s/\ell|$ will be printed. Non-symmetric matrices can be handled by using Code 91, the matrix multiplication code, to make the matrix symmetric by multiplying by the transpose. The inverted matrix is then multiplied again by the transpose.

Ordinary Differential Equations. A code for solving a system of first order ordinary differential equations by Milne's method is now working.

Since the last report the following new programs have been placed in the library:

111. Zero of a Solution of a Differential Equation. 16 Words.

This routine enters Code 114 (or the obsolete Code 27) repeatedly, adjusting the size of the steps until a selected variable y_i, chosen by a program parameter, vanishes.

112. Solution of a Set of Simultaneous Linear Algebraic Equations. 83 Words.

This code replaces Code 47 which will be withdrawn. Code 112 has had orders for decreasing read around removed and does not hang up on division.

113. Automatic Linear Equation Solver.

This code replaces Code 51 in the same way that Code 112 replaces Code 47.

114. Runge-Kutta Solution of a System of Ordinary Differential Equations. 41 Words.

This is a re-written version of Code 27, which is now considered obsolete.

115. Milne's Method for Solving a System of Ordinary Differential Equations. 46 Words.

116. Square Root. 9 Words.

This replaces Code 21 which had 10 words. The reduction in length is obtained by using one of the new K-orders.

II MACHINE USE

The following list gives problem specifications for new problems which were tried. It does not indicate how the computer was used because large amounts of machine time may have been consumed by problems with numbers less than 199.

NUMBER	PROBLEM SPECIFICATION	AFFILIATION
199	Solution of simultaneous equations	Food Technology
200	Stresses in Cylindrical Pressure Vessels	Computer
201	Product Moment Coefficients	Psychology
202	Response Pattern Analysis	Psychology
203	Boundary Value Differential Equation	Computer
204	Curve-plotting Demonstration	Computer
205	Floating Decimal Subroutines	Computer
206	Simultaneous Equations	Computer
207	Integration of Differential Equation	Physics
208	**Calculation of Covariance Matrix**	**Education**
209	**Random Walk**	**Chemistry**
210	Trajectories in Electron Cyclotron	Computer
211	Inversion of a Symmetric Matrix	Computer
212	Automatic Eigenvalues and Eigenvectors	Computer
213	Highway Impact Differential Equation	Structural Research
214	Synchrotron Orbits	Physics
215	Eigenvalues and Eigenvectors	Inst. Juv. Research
216	Dynamic Response of Structures	Structural Research
217	Eigenvalues and Eigenvectors	Psychology
218	Polynomial Approximation	Computer

Table I shows the distribution of machine time for the interval October 1 through October 31, 1953:

TABLE I

	h m
Engineering 8-12	32:15
Engineering 12-12	17:15
RAR	20:44
Leapfrog	79:54
Wasted	2:20
Use by Departments	
Computer Laboratory:	
Nash	9:44
Gill	:57
Robertson	:48
Polivka	1:28
Golub	4:53
Fishel	:24
Gregory	2:43
Seshu	1:33
Muller	2:59
Others	1:12
Classes	4:24
Physics	17:58
CSL	47:22
Structural Engineering	43:21
Struct. Eng. Nobs 62250	6:57
Struct. Eng. AF 24994	9:55
Psychology AF 25726	12:18
Education	2:25
Inst. Comm. Research	:08
Chemistry	30:56
Agriculture	3:39
Inst. for Juv. Research	:13
Public Health	3:10
Indiana University	:18
Demonstrations	6:06
Total:	368:19

III CODING MANUAL

Work is now in progress on all chapters of the coding manual, and some chapters are essentially finished.

IV DIVISION OVERFLOW STOP

The stop which is made in the Illiac when an overflow occurs in division has already proved of enormous value in code checking. A large number of coding errors, some of which might otherwise have been very difficult to detect, have been discovered because of the division overflow stop. Those library codes which were previously unaffected by improper divisions have been changed. The following useful hang-ups which occur with the division overflow stop have been observed in library routines:

(a) In Code 116 (Square Root) if the operand is negative, with the exception of -2^{-39}.

(b) In Code 75 (Integer Print) if the number of digits specified by the programmer to be printed is fewer than the number of equivalent decimal digits held in the register.

(c) In Code 23 (Input Sequence of Fractions) sometimes if a sign is omitted and the number of digits exceeds 11.

(d) In Code 88 (Fraction Input) sometimes if the number of digits being input exceeds 12.

V ERROR FREQUENCY AND ANALYSIS

The machine is normally used for "engineering" and maintenance between 8 AM and 12 N, and for a check of its performance between 5:00 PM and 5:30 PM of each weekday. Since the periods between 8 in the morning and noon, together with certain other irregular periods like Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more

instructive from an error analysis standpoint to look at the periods between noon and midnight of each weekday in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind a summary table has been prepared using the period between noon and midnight of each weekday. This table lists the running time when the machine was operating, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 5:00-5:30 period (when the machine is checked) if no errors are found, the time is given to the "running column". Each failure was considered to have terminated a running period and was followed by a repair period in preparing this Table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented as Table II.

VI COMMENTS ON THE MACHINE

During the month the red gates of the A and Q registers were wired in parallel and the black gates of the A and Q registers were wired in parallel. Previously, the gates in the Q register operated as a result of the gates in the A register in a serial fashion. The new arrangement reduces the number of series cathode followers in the gate loop. This should make the machine safer from a tolerance standpoint and should increase the speed of the gates slightly. However, no appreciable change in the speed was noted due to this change.

DATE	RUNNING OK	REPAIRS	FAILURES DURING OK TIME	TYPES OF FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES OF LEAPFROG
10/5/53	12:00	:00	0		:00	:30	0
10/6/53	10:46	1:14	4	(1) Leapfrog 2^{-37} either $1 \rightarrow 0$ loc. 25S or $0 \rightarrow 1$ loc. 25J (2) Leapfrog-reader skipped character (3) Leapfrog-chad in tape (4) Leapfrog-input-output failure	:00	2:13	4
10/7/53	11:56	:04	2	(1) Leapfrog - chad chute clogged (2) Leapfrog - chad in tape	:00	5:57	2
10/8/53	11:59	:00	0		:01	6:34	0
10/9/53	11:54	:01	1	(1) Computer failed to recognize an N at end of tape	:05	3:53	0
10/12/53	10:30	1:30	1	(1) Flaw at 3SL pos #16	:00	2:01	1
10/13/53	4:08	7:50	3	(1) Leapfrog - unknown (2) Hung up on output order (3) Failure of recognition circuit	:02	:25	1
10/14/53	11:58	:00	0		:02	1:42	0
10/15/53	12:00	:00	0		:00	1:28	0
10/16/53	12:00	:00	0		:00	1:23	0
10/19/53	11:20	:35	1	(1) Reader error	:05	1:30	1
10/20/53	12:00	:00	0		:00	:30	0
10/21/53	11:51	:08	1	(1) Reader repairs	:01	:56	0

DATE	RUNNING OK	REPAIRS	FAILURES DURING OK TIME	TYPES OF FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES OF LEAPFROG
10/22/53	11:09	:51	1	(1) Unknown	:00	:50	0
10/23/53	10:57	1:01	2	(1) Reader interpreted 4 as 0 (2) Chad in punched tape	:02	:34	0
10/26/53	11:40	:18	1	(1) Comparison failure - reader	:02	:43	1
10/27/53	11:45	:15	1	(1) Reader running very slowly	:00	:44	0
10/28/53	12:00	:00	0		:00	:46	0
10/29/53	11:54	:06	2	(1) Unknown (2) Unknown	:00	:44	0
10/30/53	12:00	:00	0		:00	1:14	0
TOTALS	225:47	13:53	20		:20	34:37	10

The machine speeds as measured after the orange gate was added can be seen from Table III.

TABLE III

MACHINE SPEEDS - OCTOBER 15, 1953

OPERATION	TIME		MEMORY PERIODS
Memory Cycle	18.8	microseconds	
Multiplication by Zeros	639^1	"	34^1
Multiplication by Ones	865^1	"	46^1
Add	75^1	"	4^1
Divide	940^1	"	50^1
Left Shift Zeros	17.9^2	"	
Left Shift Ones	18.8^2	"	
Right Shift Zeros	15.8^2	"	
Right Shift Ones	16.9^2	"	
Input from Tape	4	milliseconds	
Punch	49	"	
Display	1	"	
Print	180	"	

[1] Includes time for bringing out order and for bringing out operand.

[2] Does not include time for bringing out order.

VII RESEARCH AND DEVELOPMENT (This is supported in Part by ONR Task 24)

a. Drum Memory

Numbers have been transferred between the drum and a 40 digit register and back again on a repetitive basis for periods of 1 1/2 to 3 hours without error. During these tests the word was always transferred to a fixed address on the drum which was set in by hand switches. On some occasions errors have occurred after an hour and a half.

Tolerance checks have been made on the voltages and lengths of most of the signals which are used in the drum memory. It has been found that the +300 volt supply to the memory can be changed only by ± 1.6% without causing an error. The reason for this is not now known but is being investigated.

In order to test the drum memory in a more complete fashion, the interconnections which are necessary to the Illiac have been made. The 28 wires which serve to interconnect the drum memory and the Illiac are about 100 feet in length but should not cause any difficulty in the circuits to which they are connected.

b. Magnetic Core Switches and Memory Work

Several small models of the proposed static memory were built. These were made of cores of the metallic type. Since the access time with a steel core is dependent upon the drive, all were heavily overdriven to obtain a fast access. This process was very successful. The most recent model used 10 4-79 mo-permalloy cores as storage cores. Each of these has an inside diameter of about 1/4" and is made of 10 wraps of 1/8 mil x 1/8" mo-permalloy 4-79. As used in an ordinary dynamic magnetic memory, the turnover time is about 10 to 15 μsec. The cores driving each of the 16 lines which threaded these cores were 3/8" inside diameter and were made of 10 wraps of 0.7 mil x 1/8 Deltamax. The primary drive for the cores was 11.25 Ampere turns which was obtained by wrapping 150 turns on the core and bucking this with 75 turns, with each winding operated at 150 m.a. The time from the beginning of a drive pulse until the arrival of the signal was about 1.5 μsec due to the large amount of overdrive. The selected signal is

opposite in polarity to it. The output signal was about 100 mv. per turn of pickup coil.

Quotations have been requested and samples have been received of some types of ferrite cores which are suitable for some portions of this work.

Twenty of the experimental type RCA C-73621 cathode ray tubes have been received. These have been tested in the Williams test rack and all of them have been found to have read around ratios in excess of 1,000 and appear to be free from flaws. Plans have been made to install 40 of these in the Illiac as soon as they are available.

VIII REPORTS AND SEMINARS

Seminars:

NUMERICAL RESULTS ON THE SHOCK CONFIGURATION IN MACH REFLECTION by A. H. Taub - October 7, 1953.

THE ARITHMETIC PROGRAMMING CODE by Richard Brown - October 14, 1953.

SOME SINGLE-ADDRESS ORDER CODES by Stanley Gill - October 21, 1953.

A STATIC MAGNETIC CORE MEMORY by Joseph M. Wier - October 28, 1953.

Paper:

AN INTERPRETIVE ROUTINE FOR THE MANIPULATION OF EXPANSIONS IN BOOLEAN ALGEBRA - by David E. Muller, Association for Computing Machinery, Boston, September 10, 1953.

Internal Report:

Number 51, MINIMIZATION OF v POLYNOMIALS SUBJECT TO SUBSIDIARY CONDITIONS by D. E. Muller, October 6, 1953.

IX CONSTRUCTION

1. Fifty adapter sockets were wired to adopt the present cathode ray tube sockets on the Illiac to the bases of the new type C-73621 cathode ray tubes.

2. Parts for twenty record and playback preamplifier chassis have been made. Ten chassis have been assembled. Each chassis contains ten record and playback preamplifier circuits.

3. Minor additions were made to the Illiac to allow the drum to be connected to it. The connections between the drum and the Illiac were made.

4. An inverter chassis for the drum unit was built. (Drawing M-534).

5. Future work was carried out on the new photoelectric tape reader model.

6. Servicing of parts on the Illiac and of Teletype equipment was carried out.

X PERSONNEL

The personnel associated with the group and hence the contributors to this report are:

Brown, Mrs. Carolyn
Ehrlich, George
Fishel, Jerome (1/2 time)
Gill, Stanley
Golub, Gene (1/2 time)
Gregory, R. T. (1/4 time)
House, Mrs. Natalie R.
Huffman, W. L.
Jones, W. E.
Kerkering, T. E
Kudlich, R A. (RCA Fellow)
Lopeman, H. E
Meagher, R. E.

Michael, G. W.
Miller, R. E. (1/2 time)
Muerle, J. L. (1/2 time)
Muller, D. E.
Nash, J. P.
Newmark, N. M. (Chairman, Executive Committee)
Ogata, Albert I. (Student Assistant)
Polivka, R. P. (1/2 time)
Robertson, J. E.
Russell, Miss Ramona
Seinfeld, Robert (Student Assistant)
Seshu, Mrs. Lily (1/2 time)
Shapin, Theodore Jr.
Stephens, Allen
Taub, A. H. (1/2 time)
Wier, J. M.
Yu, Ha-Nien (1/2 time starting November 1, 1953)

The work of the group is under the administration of an Executive Committee with the following members: N. M. Newmark, Chairman, Stanley Gill, D. E. Muller, J. P. Nash, J. E. Robertson, A. H. Taub and R. E. Meagher.

R. E. Meagher

REM/nrh

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UNIVERSITY OF ILLINOIS

GRADUATE COLLEGE

DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

November 1, 1953 - November 30, 1953

I MATHEMATICAL RESEARCH AND CODING (This work is supported in part by ONR Task 30)

Magnetic Drum Codes. Attention is being given to the problems which will arise when the magnetic drum memory is added to the Illiac. A code of fundamental importance will take subroutines from the drum and put them into the Williams memory. A drum test code using pseudo-random numbers has also been prepared.

Boundary Value Differential Equation. This program for solving second order differential equations with two-point boundary conditions is now working. However, since it is not in closed subroutine form it cannot be entered repeatedly. The modifications necessary for making it into a closed subroutine are now being made.

Electrical Network Problems. Certain classes of problems in electrical network theory are difficult to solve even by analog methods. A study is being made to see if digital techniques will be helpful.

Since the last report the following new programs have been placed in the library. Code 120 was prepared by R. S. Hansen of the Electrical Engineering Department.

118. Automatic Inversion of a Symmetric Matrix.

This program will take the elements of a symmetric matrix punched on the input tape (and scaled so that $\sum a^2_{ij} < 1/4$) and will punch out the elements of the inverse. The condition of the matrix being inverted is indicated by the ratio n/N of smallest and largest eigenvalues, which is punched at the end. The program is limited to matrices no larger than 23 by 23; the time for the largest matrix is about 14 minutes.

119. Plot Axes and Points on the Cathode Ray Tube. 21 Words.

This code will plot a set of axes and mark them at equal intervals, the origin and the number of marks being determined by program parameters. It will then plot points with reference to the origin of coordinates. The time required is 0.8 second for the marked axes and about 2 milliseconds for each plotted point.

120. Tshebyscheff Polynomials. 15 Words.

This code computes the value of the Tshebyscheff Polynomials $T_r(x) = \cos r\ (\cos^{-1} x)$ up to $r = n$ when entered with the program parameter n with x in in the accumulator. The time required is about 1.3n milliseconds.

II MACHINE USE

The following list gives problem specifications for new problems which were tried. It does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 219.

NUMBER	PROBLEM SPECIFICATION	AFFILIATION
219	Solution of Simultaneous Algebraic Equations	Agr. Economics
220	Factor Analysis by Square Root Method	Psychology
221	Simultaneous Second Order Differential Equations	Structural Lab.
222	Monte Carlo method for electron spins	Special
223	Least square method for diffusion equation	Physics

NUMBER	PROBLEM SPECIFICATION	AFFILIATION
224	Product moment correlations	Psychology
225	Calculation of associated Legendre polynomials	Elect. Eng.
226	Calculation of stresses in pressure vessels	Computer
227	Calculation of eigenvalues and eigenvectors	Inst. for Juvenile Research
228	Meson Nuclear Potentials	Physics
229	Calculation of Multiple Regression	Agr. Economics
230	Matrix Multiplication	Inst. for Juvenile Research
231	Orthogonal transformation of factor loadings matrix	Psychology

Table I shows the distribution of machine time for the interval November 1 through November 30, 1953. (Next Page)

TABLE I

	[illegible]
Engineering 8-12	[illegible]:24
Engineering 12-12	[illegible]:40
RAB	[illegible]:42
Leapfrog	33:45
Wasted	:47
Demonstrations	1:31
Use by Departments	
Computer Department	
Gill	1:39
Nash	2:27
Polivka	2:33
Golub	:38
Fishel	:55
Gregory	:47
Seshu	:59
Muller	1:25
Others	:33
Classes	12:49
Physics	37:39
Cosmotron	3:09
Control Systems Lab	41:05
Structural Research	
(a) non contract	21:07
(b) AF 24994A	6:16
Psychology	
(a) non contract	:02
(b) 25726G	:14
(c) 25726A	12:00
Education	2:58
Electrical Engineering	1:58
Chemistry	45:29
Agriculture	1:51
Fosdick (Special)	3:12
Inst. for Juvenile Res.	1:44
Public Health	10:40
Total:	325:58

III ERROR FREQUENCY AND ANALYSIS

The machine is normally used for "engineering" and maintenance between 8 AM and 12 N, and for a check of its performance between 5:00 PM and 5:30 PM of each weekday. Since the periods between 8 in the morning and noon, together with certain other irregular periods like Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more instructive from an error analysis standpoint to look at the periods between noon and midnight of each weekday in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind a summary table has been prepared using the period between noon and midnight of each weekday. This table lists the running time when the machine was operating, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 5:00-5:30 period (when the machine is checked) if no errors are found, the time is given to the "running column". Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented as Table II.

It is important to notice that any interruption of machine time that was not planned for is considered a failure in this table.

In rare cases where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This overall system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" at any instant of time and the probability of a failure during any given interval of running time. On this basis it can be ascertained from Table II that the machine was running 216 hours 12 minutes out of a total planned operating time of 232 hours 5 minutes. The 232 hours 5 minutes is obtained by noting that the machine was on 12 hours a day for 20 days except for an irregularity associated with Thanksgiving which reduced the time by 7 hours 55 minutes. The probability of the machine being in a running state is 216 hours 12 minutes/232 hours 5 minutes or 0.93. During the 216 hours 12 minutes time 19 errors were found giving an error rate of 0.088 per hour.

IV COMMENTS ON THE MACHINE

For most problems the input and output time is a small fraction of the total operating time. For these problems the Illiac may be considered to do about 10,000 arithmetic operations of the complexity of an add order per second on 40 binary digits. Sine the machine had 19 errors in 216 hours the total number of binary digital add operations per error is:

$$10^4 \text{ x } 40 \text{ x } 3.6 \text{ x } 10^3 \text{ x } 216/19 \approx 16.4 \text{ x } 10^9$$

An error was found in the logic associated with the reading of a paper tape and it was corrected. This error was that the end

DATE	RUNNING OK	REPAIRS	FAILURES DURING OK TIME	TYPES OF FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES OF LEAPFROG
11/2/53	11:53	:05	1	Flaw at 05K tube 28	:02	1:02	1
11/3/53	11:13	:46	2	(1) Control error	:01	:18	0
				(2) Reader error. Light loose in socket			
11/4/53	10:56	1:02	1	(1) Runover of maintenance time	:02	1:33	0
11/5/53	4:28	7:09	3	(1) Due to new drum connections	:23	:07	1
				(2) " " " " "			
				(3) " " " " "			
11/6/53	12:00	00:00	0		:00	:48	0
11/9/53	11:57	:03	1	(1) Comparison failure, occasional input-output test, otherwise unknown	:00	1:12	1
11/10/53	11:58	:02	0		:00	:39	0
11/11/53	12:00	:00	0		:00	:46	0
11/12/53	10:37	1:23	2	(1) 0 → 1 add. 3LL pos 12	:00	:21	2
				(2) Punch failure due to incorrect input logic			
11/13/53	11:38	:19	1	(1) Failure in scope output circuit	:03	:30	0
11/16/53	12:00	00:00	0		:00	:28	0
11/17/53	12:00	00:00	0		:00	:23	0
11/18/53	11:59	00:00	0		:01	:23	0

DATE	RUNNING OK	REPAIRS	FAILURES DURING OK TIME	TYPES OF FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES OF LEAPFROG
11/19/53	11:42	:18	1	(1) Failure associated with new photo reader	:00	:24	0
11/20/53	8:40	3:19	1	(1) Caused by failure of C.R. chassis 32	:01	:24	0
11/23/53	11:25	:35	1	(1) Reader failure	:00	:32	0
11/24/53	11:59	:01	1	(1) Unknown	:00	:27	0
11/25/53	10:02	:01	1	(1) Caused by pos 6. (Tube changed)	:02**	:36	0
11/27/53	6:00	:00	0		:00*	:00	0
11/30/53	11:45	:15	3	(1) Reader error (2) Flaw 0 → 1 at 37L pos 6. (3) Reader error	:00	1:05	1
TOTALS	216:12	15:18	19		:35	11:58	6

* Machine off at 10:05 PM Thanksgiving

** Machine off at 6:00 PM

signal for a read order was obtained after the character was read but before the tape reader advanced the character. This is believed now to have caused errors on rare occasions.

Some additional Teletype equipment has been put into operation. Some additional changes are being made in the Teletype printers so that they may all print a full set of characters.

V RESEARCH ON COMPUTER COMPONENTS (This is supported in part by ONR Task 24)

a. Drum Memory

Shortly after the drum test circuits were connected to Illiac, some leapfrog errors occurred occasionally that were hard to diagnose. It was finally traced to the C.F's that supply the address digits to the drum circuits. The capacity load of the wires in the 100 foot cable caused enough grid current to flow to send the wrong address digits to the dispatch counter. The trouble was fixed by connecting two C. F's in series to drive the wires.

The 40 volt grid signals to the playback gates in RI are capacitively coupled to all the other wires in the cable and eventually get back into the playback amplifiers via the address digit wires and the 815 selection tubes. This was enough to prevent proper playback of a recorded word. It may be necessary to shield these wires. At present, the test unit is being run on one track as selected by a battery voltage. Illiac codes have been written for recording, playing back and checking, words with several "densities" of 0's and 1's. These have run successfully for several minutes.

b. Transistor Circuits

Further investigations are being made of the hole storage effects. An experiment was carried out to determine whether any significant decrease in hole storage duration would result from driving the emitter voltage considerably negative, rather than simply returning it to zero to cut off the transistor. Measurements on ten transistors showed that a slight decrease in delay time results, but this is only about 15% of the delay time. A typical result was a decrease from a 16 μsec delay time to 14 μsec, when the emitter was driven seventy volts negative. This improvement is obviously not significant as a practical answer to the hole storage problem.

Tests are being made to determine whether the use of a clamping diode to maintain a minimum voltage from collector to base will offer a solution. The purpose of the diode would be to maintain the transistor in the active region, as distinguished from the saturation region, even with large emitter currents. Tests are also being made in order to verify some results reported by the group at Lincoln Laboratory, and to find out if there is a consistent relation between "turn-off time" and "fall-time". "Turn-off time" is the delay between the cut-off of emitter current and the initial response at the collector. "Fall-time" is the time required for the collector to reach some arbitrary point, say 90% of the decrease in collector voltage.

Hole-storage and transient time measurements will be made on junction transistors when these are received.

It was decided that it would be worthwhile to investigate the use of junction transistors in computing circuits. Several types of transistors were ordered from different manufacturers.

Some preliminary consideration has been given to series-connected current-type logic circuits for junction transistors. A prototype "and" circuit (two inputs) was built, but many objections to this are obvious.

VI REPORTS AND SEMINARS

Seminars

Algebraic Analysis of Asynchronous Control Circuits
by David E Muller - November 4, 1953.

The Nature of Programming
by Stanley Gill - November 11, 1953.

Studies of Air Pollution Control Methods Using the Illiac
by H. F. Kraemer - November 18, 1953.

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Papers

Diagnostic Programs for the Illiac by David J. Wheeler and James E. Robertson (Proceedings of the I.R.E.) October 1953.

Boolean Algebras in Electric Circuit Design by David E. Muller (American Mathematical Society) November 27, 1953.

The Geometric Structure of Shock Configuration by A. H. Taub. (Northwestern University, Joint National Research Council and American Math Society. Symposium on Special Topics in Applied Mathematics.) November 28, 1953.

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Internal Reports

#52 by Joseph M. Wier, A STATIC MAGNETIC MEMORY.

VII CONSTRUCTION

1. A new ac turn-on panel, which includes memory filaments, was built and installed.

2. Twenty drum pre-amplifier chassis were built and six chassis were wired. (Drawing L503).

3. Forty plug adapters for new cathode ray tubes were made.

4. A simple photoelectric tape reader was finished. It will read 265 characters per second and stop in 0.025 in. after receiving a stop signal.

5. New cover and chad box for old punch.

VIII PERSONNEL

The personnel associated with the group and hence the contributors to this report are:

Brown, Mrs. Caroline
Ehrlich, George
Fishel, Jerome (1/2 time)
Gill, Stanley
Golub, Gene (1/2 time)
Gregory, R. T. (1/4 time)
House, Mrs. Natalie R.
Huffman, W. L.
Jones, W. E.
Kerkering, T. E.
Kudlich, R. A. (RCA Fellow)
Lopeman, H. E.
Meagher, R. E.
Michael, G. W.
Miller, R. E (1/2 time)
Muerle, J. L. (1/2 time)
Muller, D. E.
Nash, J. P.
Newmark, N. M. (Chairman, Executive Comm.)
Ogata, Albert I (Student Assistant)
Polivka, R. P. (1/2 time)
Robertson, J. E.
Russell, Miss Ramona
Seinfeld, Robert (Student Assistant)
Seshu, Mrs. Lily (1/2 time)
Shapin, Theodore Jr.
Stephens, Allen
Taub, A. H. (1/2 time)
Wier, J. M.
Yu, Ha-Nien (1/2 time)

The work of the group is under the administration of an Executive Committee with the following members: N. M. Newmark, Chairman, Stanley Gill, D. E. Muller, J. P. Nash, J. E. Robertson, A. H. Taub and R. E. Meagher.

Ralph E. Meagher.

REM/nrh

UNIVERSITY OF ILLINOIS

GRADUATE COLLEGE

DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

December 1, 1952 to December 31, 1952

I MATHEMATICAL RESEARCH AND CODING (This work is supported in part by ONR Task 30)

Electrical Network Problems. A study of 3-phase electrical network problems by use of symmetrical components is being made. As a preliminary step some new routines for the handling of complex numbers are being prepared.

Boundary Value Differential Equation. Although this program is now operating as a closed subroutine, a few more changes are being made to polish it up. The range of integration is being made L with $\Delta = L/n$ instead of $1/n$.

Statistics Problems. A code estimating factor loading by the method of maximum likelihood is now being prepared.

Boolean Algebra and Feedback Circuit Theory.

(a) A broader criterion for establishing the speed independence of a circuit has been found which includes previous criteria as special cases. This criterion is still sufficient but not necessary, as examples show. Certain static circuits fail to satisfy this criterion.

(b) In order to formulate this criterion a new concept of time had to be introduced having the following unusual properties:

1. It is discrete
2. It is only partially ordered.
3. It is local, any given time applying to a particular point.

(c) A method for building a circuit from partial circuits is now being developed which will preserve time independence.

Boolean Algebra and Error Detection Theory. A machine program was written to find nets of logical variables which are incomplete in the sense that additional points can be found satisfying the distance condition but not lying in the net. (Theorem 26 of Internal Report 46 proves there are an infinite number of these). In the case of 7 variables one such incomplete net was found (of order 16) and in the case of 8 variables three were found (of orders 16, 32 and 64). This still leaves the 6 variable case as the only one for which the question has not been answered one way or the other. (The 5 variable case was shown in a previous investigation to have no incomplete nets).

NEW PROGRAMS FOR THE LIBRARY. Since the last report the following new programs have been placed in the library:

121. Constant Listing Auxiliary for Floating Decimal. 18 words.

This program is used with Code 63. When a constant is wanted - as, for example, "add 0.005 into the accumulator" - the constant is used for the address in the add order. Code 121 stores the constant in a list and furnishes the add order with the correct address. Values already in the list are not repeated.

123. Polynomial Approximation. Complete Program.

This program prints the coefficients of a polynomial which approximates to the function kf(ax + b) over the range $c \leq x \leq d$ where in practice the origin is inside the range. The function f is defined by a Taylor series $f(y) = f_o + f_1 y + f_2 y^2 + \ldots$, the coefficients of which may be either given numerically or generated by an auxiliary routine. Any number of coefficients up

through f_{100} may be given. Because of accumulating roundoff errors the program should not be used if $(1/20) < (c/a) < 20$.

124. Letter Printing. 32 words.

This is a closed routine with 3 methods of entry which is designed to simplify printing of letter groups and to conserve memory space when large numbers of letters are to be printed. It may be entered:
(a) so as to store in compact form 5-hole tape characters;
(b) so as to print characters stored as in (a); or (c) so as to read from the tape and print immediately without storing.

125. Convert A Number from Floating Decimal Representation to Normal Machine Form. 27 words.

An auxiliary for Code 63, this code will accept a floating point decimal number in the floating accumulator and leave a fixed point binary number in the AQ register with the point at the end of A.

126. Sine Auxiliary for Floating Decimal. 26 words.

This code is an auxiliary for Code 63 and also uses Code 125. It takes the number x from the floating accumulator and replaces it with sin x.

127. Exponential for Floating Decimal. 26 words.

Replacing Code 102, this code takes the number x from the floating accumulator and replaces it with e^x. Code 125 is used by Code 127.

128. Floating Decimal Tape with Standard Auxiliaries.

This tape contains programs 63, 125, 92, 126, 127, 96 and 121 arranged for convenient use by means of S-parameters.

ENGINEERING CODES. A second library of codes is kept for engineering purposes. At present the library of engineering codes contains the following codes.

5. Input Test. Successive pairs of numbers on a check tape are read and added. In case of failure the pair of words is printed.

6. Punch Test. Successive integers are formed and punched.

7. Punch and Input Test. An output tape from the punch is read by the reader. Words of all possible lengths are then read and punched.

8. Illinois Adder Test. This test checks all possible combinations in each of the 40 stages of the adder and prints indicating quantities when a failure occurs.

9. Single Digit Adder Test. A single stage of the adder is tested.

10. Programmed and Partial Multiplication Tests. After computing and storing the contents of A and Q at each step of a multiplication for two 10-sexadecimal-digit numbers x and y read from a tape, two tests are performed:

    a. Using the last i digits of the multiplier, a multiplication is executed and the i^{th} partial product is compared (for each i) with the corresponding partial product which was stored;

    b. Using the first 39-i digits of the multiplier, a multiplication is executed which uses the results of the i^{th} partial product which have been stored. The result is compared with xy.

    The program prints pertinent data when errors are indicated.

11. Control Transfer Test. This code tests the address gates necessary for control transfer orders by transferring cyclically through a set of 64 selected addresses. If a single-digit error occurs there is a stop and the error is indicated.

12. Sexadecimal Post Mortem. This code will print location and sexadecimal contents of the non-zero memory content from 3 to 3LL or of selected locations.

13. Sexadecimal Input. (Miniature Bootstrap). This code places 10-digit sexadecimal words at locations each of which is specified by a 3-digit sexadecimal address.

14. Switch Controlled Print Routine. The contents of the memory are printed beginning at a location whose 6 most significant binary digits are set by manipulating the control switches.

15. Plant Address Test Routine. The memory is filled with L5n L5n at each location n.

16. Read Around Adjustment. The memory is tested for read around failures, reading a test number from the tape when requested by moving a panel switch. Visual inspection of the memory is required.

17. Orange Leapfrog. This is the standard program used to test the Illiac. A few modifications were made when the orange gate was added, but it is essentially the same as the Leapfrog II code described in the report of February 25, 1953.

18. *Leapfrog Crippler with Special Tests.* This code makes it possible to cripple the Orange Leapfrog (run it without leaping) and to do the special tests which the Orange Leapfrog does only after certain leaps.

19. *Print Decimal Order Input.* This code is described by the title.

20. *Abstract of Leapfrog Special Tests.* The occasional tests in the Orange Leapfrog are done.

21. *Duplex Read Around.* The standard read around test for the Illiac, this code bombards each memory location n times (where n is read from the tape) and checks surrounding locations for failures. Failures in both direction are checked. When a failure occurs there is printed tube number, location, and type of failure.

22. *Machine Timing Program.* The basic memory cycle time and the times for 12 fundamental machine operations are calculated and printed. On each test a closed loop is entered and the operation is run repetitively for one minute and stopped with a panel switch.

23. *Caterpillar.* This is a visual read around test which bombards each point 665 times as it moves through the memory.

24. *Black Switch Test.* Using appropriately placed control transfer orders, this code checks correct operation of the start switch on the panel.

25. Compare Sexadecimal Tapes. Two tapes are compared by comparing sexadecimal characters.

26. Light Neons. All neons in A, Q and the control counter are turned on.

II MACHINE USE

The following list gives problem specifications for new problems which were tried in December. It does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less then 232.

NUMBER	PROBLEM SPECIFICATION	AFFILIATION
232	Solenoid fields	Physics
233	No record	. .. . .
234	Eigenvalues and eigenvectors	Psychology
235	Quadrimax matrix analysis	Psychology
236	Stellar interiors integration	Indiana Univ.
237	Matrix multiplication	Inst. Juv. Res.
238	Ranked numbers	Inst. Juv. Res.
239	Caterpillar read around test	Computer
240	Product moment correlation	Phys. Ed.
241	Deuteron wave function	Physics
242	Letter printing	Computer
243	Matrix multiplication	Psychology
244	Solution of Laplace equation	Elec. Engr.
245	Solution of Boltzmann's equation	Physics
246	Eigenvalues and eigenvectors	Education
247	Quadrimax matrix analysis	Education
248	Analysis of simple ciphers	Shapin
249	Estimation of communalities	Psychology
250	Product moment correlation	Bureau Ed. Res.
251	Special factor analysis	Computer

NUMBER	PROBLEM SPECIFICATION	AFFILIATION
252	Cross section analysis	Physics
253	Eigenvalues and eigenvectors	Computer
254	Error detection problem	Computer
255	Highway bridge impact	Struct. Engr.

Table I shows the distribution of machine time for the interval December 1, 1953 to December 31, 1953:

TABLE I

	h m
Engineering 8-12	29:01
Engineering (All other times)	13:58
RAR	24:53
Leapfrog	42:08
Wasted	1:40
Demonstrations	2:41
USE BY GROUPS	
Computer Group	
Gill	:51
Nash	4:45
Robertson	2:17
Polivka	:47
Golub	1:54
Fishel	3:37
Seshu	:28
Muller	3:26
Others	16:04
Classes	6:06
Other Groups	
Physics	37:58
Cosmotron	6:43
CSL	48:47
Struct. Res. (Reg.)	6:24
Struct. Res. AF 24994	22:11
Psychology (Reg.)	1:38
Psychology AF 25726A	17:54
Psychology AF 25726G	1:25
Electrical Engineering	1:55
Chemistry	21:52
Agriculture	1:21
Physical Ed.	1:27
Public Health	2:25
Miscellaneous Users	7:51
Total	344:27

III ERROR FREQUENCY AND ANALYSIS

The machine is normally used for "engineering" and maintenance between 8 AM and 12 N, and for a check of its performance between 5:00 PM and 5:30 PM of each weekday. Since the periods between 8 in the morning and noon, together with certain other irregular periods like Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more instructive from an error analysis standpoint to look at the periods between noon and midnight of each weekday in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind a summary table has been prepared using the period between noon and midnight of each weekday. This table lists the running time when the machine was operating, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 5:00-5:30 period (when the machine is checked) if no errors are found, the time is given to the "running column". Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented as Table II.

It is important to notice that any interruption of machine time that was not planned for is considered a failure in this table.

DATE	RUNNING OK	REPAIRS	FAILURES DURING OK TIME	TYPES OF FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES OF LEAPFROG
12/1/53	11:10	:50	1	(1) Light bulb connection on reader bad	00	:31	0
12/2/53	11:41	:00	0		:19	1:06	0
12/3/53	11:45	:15	1	(1) Morning Eng went by 12:00	:00	1:07	0
12/4/53	11:47	:13	3	(1) (2) } All due to reader (3)	:00	:30	1
12/7/53	11:46	:14	2	(1) Memory error 1 to 0 in tube 8 (2) Reader error	:00	:50	1
12/8/53	11:53	:01	1	(1) Tape reader error	:06	:42	0
12/9/53	12:00	:00	0		:00	:33	0
12/10/53	11:53	:07	1	(1) Leapfrog (type of error unknown)	:00	2:07	1
12/11/53	10:04	1:55	4	(1) Reader error (2) L. F. (not noted) } due to chassis in (3) Demonstration } mem. pos. 36 (4) L. F (not given)	:01	1:42	2
12/14/53	11:35	:01	1	(1) Reader error	:24	1:42	0
12/15/53	8:41	3:17	2	(1) 0 → 1 pos. 32 (2) 0 → 1 pos. 32	:02	3:52	3
12/16/53	11:59	:01	1	(1) Reader error	0	1:27	0

DATE	RUNNING OK	REPAIRS	FAILURES DURING OK TIME	TYPES OF FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES OF LEAPFROG
12/17/53	11:08	:52	1	(1) Filement in tube 14 address gen. failed	:00	1:28	0
12/18/53	9:55	1:59	4	(1) Ignored 24 order (2) A.C. went off (3) Reader error (4) Tape from punch broken	:06	:22	0
12/21/53	6:53	5:07	4	(1) Reader error (2) Ignoring 24 orders (3) Ignored 20 order (4) Reader light burned out	:00	:21	0
12/22/53	10:40	1:20	1	(1) Tube 24 arith. control bad (cause of errors preceding day)	:00	:29	0
12/23/53	11:40	:15	1	(1) 0 → 1 pos. 32 intensity too low	:05	:34	1
12/24/53				No period for error analysis			
12/25/53				Computer Lab Closed			
12/28/53	11:53	:07	1	(1) Unknown	:00	:23	0
12/29/53	10:41	1:19	3	(1) Stopped on 34 order (2) Unknown (3) Unknown	:00	:46	1

TABLE II

DATE	RUNNING OK	REPAIRS	FAILURES DURING OK TIME	TYPES OF FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES OF LEAPFROG
12/30/53	11:58	:00	0		:02	1:04	0
12/31/53	6:40	:07	0	Lab Closed at 6:47 PM	:00	:06	0
Totals	227:42	18:00	32		1:05	21:42	10

In rare cases where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This overall system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" at any instant of time and the probability of a failure during any given interval of running time.

IV COMMENTS ON THE MACHINE

a. New Memory Tubes

A set of 60 RCA C73621 cathode ray tubes (especially developed for Williams storage on a Bureau of Ships contract) has been received. Forty tubes of the set were installed in the Illiac on December 3. As a direct result of this, the RAR in the machine was increased from a guaranteed 60 to a guaranteed 250. There has been some gradual increase in RAR since that time, but this may be due to a gradual decrease in signal size with age. It may, therefore, be necessary to increase the beam currents by adjustment.

Since the installation of the new set of tubes, three of the original set have been changed. Two were changed because the RAR in them was consistently lower than the others (although still as good as 250). The third was changed because the signals were abnormally low even though the drive circuits were in a satisfactory condition. The exact reason for this is not known.

During the month four errors could be attributed to the memory. Two of these can be classed as due to misadjustment of

the intensity, one was due to a failure of a tube in a regeneration chassis and the fourth was due to a filament failure in the address generator. Of course, there were several machine errors which were undiagnosed and may have been in the memory. There were no "flaw" errors of the type which in the past usually accounted for about five to ten errors per month.

There is some difficulty in getting a RAR test at high test values of RAR using the machine. Useful codes do not produce a RAR greater than about 200. However, a test routine which is still versatile enough to test for failures from 0 to 1, or 1 to 0, using bombardments of either 1's or 0's, reading or storing, has been written which tests for a RAR of 665. It is called the Caterpillar and requires a visual read-out of the results.

b. New Input Order.

A new order (91004) is now available which makes it possible to read all five holes from the teletype tape into the machine. The usual four are inserted in the 2^{-36} - 2^{-39} positions in the accumulator (A register) and the content of the fifth hole is put into position 2^{0} of the accumulator.

c. New Teletype Printer.

A new printer has been connected to the Illiac which contains all of the letter characters of the alphabet as well as the usual sexadecimal characters. It operates from what is expected to be the

"final" tape code. Other printers will be altered to make possible the use of this same code for all the letters of the alphabet.

d. Measurements of Speed.

During the month it was found that a pair of L5 orders required 10 regeneration cycles rather than the 8 which had heretofore been measured for a pair of L4 orders. This was found to be due to the fact that "go enable" was slow because of an added capacitance due to the drum circuits and because the "carry delay" was set too long. Both of these have been corrected so that a pair of L5 orders now require 8 regeneration cycles.

V RESEARCH ON COMPUTER COMPONENTS (Supported in part by ONR Task 24)

A new code to test drum circuits was prepared. It fills desired tracks with pseudo-random numbers, plays them back and checks them. If an error is made, the position of the incorrect binary digits is indicated. This code has only been used a total of about two hours with two tracks. However, it appears that one track will operate about 15 minutes before an error is made and the other will operate only one minute before an error is made. This is caused by noise from other circuits which is superimposed on the playback signals. The signals are not as "clean" as those obtained with the earlier test circuits. Some of the noise arises only when the drum is operating with Illiac.

Experiments have been carried out on a number of point-contact transistors to determine the effectiveness of a clamping diode

from base to collector in reducing the hole-storage effect. Results of these tests indicate that a significant reduction in hole-storage delay time can be obtained in this manner. In addition, the "turn-off time" becomes negligible when the diode is used. One more aspect of this must still be investigated. It is known that the normal delay increases with such factors as duration of saturation, but levels off at a maximum value of about 200 microseconds. The tests made so far did not involve a normal delay time of this maximum value, and therefore it is not known whether the diode-clamped delay time will also level off at an appreciably smaller delay.

Two types of junction transistors, 2N36 and 2N38, have been obtained from CBS-Hytron. They differ principally in that the 2N36 has a higher gain than the 2N38. Measurements of zero-emitter collector current (i_{co}), grounded-emitter and grounded-base current gain (α_{ce} and α_{cb} respectively) have been made for all of the 2N36's. Similar measurements will be made of the 2N38's, and response time measurements will be made for both types.

Design techniques for transistors are complicated by the relatively low impedance levels of the device. With direct-coupled circuits, this means that the voltage levels in a circuit will be altered whenever an additional circuit is connected to it. Accordingly, a junction transistor flip-flop circuit has been designed which includes two gating transistors and two read-out transistors as an integral

part of the design. This circuit was built and some tests have been made on it, using the type 2N38 transistors. The time required to turn the flip-flop over ranges from six to thirteen microseconds, depending upon the transistors in the circuit. It remains to be determined whether this circuit, or a similar one, is capable of driving a reasonable number of logical circuits.

VI REPORTS AND SEMINARS

Seminars

Nerve Cell Counting and Sizing Using the Illiac, by Walter Welkowitz - December 2, 1953.

Use of Illiac in Solving a Problem of Refraction of a Shock Wave, by A. R. Robinson - December 9, 1953.

Restricted Random Walks and the Dimension of Polymer Molecules, by W. F. Atchison - December 16, 1953.

. . . .

Papers

Reliability and Characteristics of the Illiac Electrostatic Memory by Joseph M. Wier (The Eastern Joint Computer Conference) Washington, D. C. - December 9, 1953.

Internal Reports

#53 by Joseph M. Wier, OPERATIONAL RESULTS USING C73621 CATHODE RAY TUBES AS STORAGE TUBES IN THE ILLIAC.

Talks

A series of four talks on the computer was presented for the E. E. Seminar during November and December by J. E. Robertson, J. M. Wier, T. Shapin and R. E. Meagher.

VII CONSTRUCTION

1. Twelve drum pre-amplifier chassis have been wired.
2. One Thousand 6J6 tubes were checked.
3. The construction of a set of push buttons for R_3 has been started.
4. Design of the drum frame and cabinet has been partly finished.
5. Changes were made in the Illiac to install the fifth hole input order.

VIII PERSONNEL

The personnel associated with the group and hence the contributors to this report are:

Bateman, Wm. E. (Dec. 21, 1953)
Brown, Mrs. Caroline
Ehrlich, George
Fishel, Jerome (1/2 time)
Gill, Stanley
Golub, Gene (1/2 time)
Gregory, R. T. (1/4 time)
Hardy, H. V. (Jan. 11, 1954)
House, Mrs. Natalie R.
Huffman, W. L.
Jones, W. E.
Kerkering, T E.
Kudlich, R. A. (RCA Fellow)
Lopeman, H. E.
Meagher, R. E.
Michael, G. W.
Miller, R. E. (1/2 time)
Muller, D. E.
Nash, J. P.
Newmark, N. M. (Chairman, Exec. Comm.)
Ogata, Albert I. (Student Assist.)
Polivka, R. P. (1/2 time)
Robertson, J. E.
Russell, Miss Ramona J.
Schafeld, Robert (Student Assist.)
Seshu, Mrs. Lily (1/2 time)
Shapin, Theodore Jr.
Stephens, Allen
Taub, A. H. (1/2 time)
Wier, J. M.
Yu, Hwa-Nien (1/2 time)

The work of the group is under the administration of an Executive Committee with the following members; N. M. Newmark, Chairman, Stanley Gill, D. E. Muller, J. P. Nash, J. E. Robertson, A. H. Taub and R. E. Meagher.

R. E. Meagher.

REM/nrh

UNIVERSITY OF ILLINOIS
GRADUATE COLLEGE
DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

Teaching and graduate research are
not, in general, reported herein.

January 1, 1954 - January 31, 1954

I MATHEMATICAL RESEARCH AND CODING. (This work is supported in part by ONR Task 30)

Boundary Value Differential Equation. This program has now been polished up and is being put into the library. All of the parameters except that for indicating the number n of subintervals have been made preset parameters.

Drum Transfer Routine. A program has been written, but not tested for transferring subroutines from the drum to the Williams memory. It handles block units consisting of 8 bits. It has the following advantages:

a. Subroutines stored on the drum in this fashion will generally take up less room than they will in their final form in the Williams memory.

b. It will be possible to write a routine to read tapes prepared for the Decimal Order Input and store them on the drum in the drum form without rewriting the library routines.

c. It will be possible to refer to the drum within the framework of the Decimal Order Input. A program could consist of some drum codes and some tape codes and both could be called for by similar directives. The principal disadvantage of this method is that it will probably be slower than the others.

Statistics Problems. There is now operating a routine which estimated communalities by the method of maximum likelihood. The rate of convergence, however, is very slow, and several suggestions for speeding up the convergence rate will now be investigated.

A program is also being written which will plot scatter diagrams

on the oscilloscope.

Linear Programming. A scheme has been outlined for a routine which uses the simplex method for solving problems in linear programming and the theory of games. Most attention has been paid to the conservation of memory space.

Boolean Algebra. A revision of Internal Report 46 is under way, Chapter 3 being revised substantially. A reformulation of the postulates of the new algebra presented there is being attempted, and quite a number of simplifications have been achieved.

Engineering Routines. The library of engineering programs used in Illiac maintenance (see last month's report) has been rearranged and descriptions have been furnished for all programs. The engineers' books have been arranged in four categories:

A. Leapfrog Programs (Detection)
B. Special Isolation Programs
C. Service Programs
D. Auxiliary Programs

The rack of tapes in the computer room and the file drawers of engineering programs are complete and the tapes are readily available.

II ILLIAC PROGRAMMING BOOK.

Final copy for nearly all of the chapters of the book on Illiac programming has been written and the pages are now being duplicated.

III REORGANIZATION OF THE PROGRAM LIBRARY.

It has been recognized for some time that the program library

would benefit from a reorganization, and such a reorganization is now being carried out. The old method merely numbered routines serially. The new one divides them into categories (of which there are 24) designated by letters with numbered programs in each category. The reorganization is described in Internal Report No. 55, "Reorganization of Illiac Library".

IV MACHINE USE.

The following list gives problem specifications for new problems which were tried in January. It does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 256.

NUMBER	PROBLEM SPECIFICATION	AFFILIATION
256	Esthetic connotations	Mass. Communications
257	Monte Carlo scattering	Physics
258	Pattern analysis	Psychology
259	Stresses in pressure vessels	Computer
260	Deuteron reaction	Physics
261	Transistor amplifier design	Computer
262	Auto-correlation	Psychology
263	Square root factor analysis	Inst. Labor and Ind. Rel.
264	Compute α-α cross section	Physics
265	Transient response of a ring	Struct. Engr.

Table I shows the distribution of machine time for the interval January 1, 1954 to January 31, 1954:

TABLE I

	h m
Engineering 8-12	39:56
Engineering (all other times)	16:14
RAR	15:58
Leapfrog	37:06
Wasted	:47
Demonstrations	1:46

USE BY GROUPS

Computer Group	29:20
Classes	3:49
Physics	47:18
Cosmotron	10:18
C. S. L.	38:56
Struct. Engr. (Reg.)	4:13
Struct. Engr. AF24994	8:56
Struct. Engr. NOBS62250	5:11
Psychology (Reg.)	2:14
Psychology AF25726	19:58
Elec. Engr.	3:37
Chemistry	17:50
Agriculture	5:18
Public Health	:47
Miscellaneous	18:57
Total	328:29

V ERROR FREQUENCY AND ANALYSIS.

The machine is normally used for "engineering" and maintenance between 8 AM and 12 N, and for a check of its performance between 5:00 PM and 5:30 PM of each weekday. Since the periods between 8 in the morning and noon, together with certain other irregular periods

like Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more instructive from an error analysis standpoint to look at the periods between noon and midnight of each weekday in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind a summary table has been prepared using the period between noon and midnight of each weekday. This table lists the running time when the machine was operating, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 5:00-5:30 period (when the machine is checked) if no errors are found, the time is given to the "running column". Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented as Table II.

It is important to notice that any interruption of machine time that was not planned for is considered a failure in this table. In rare cases where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This overall system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running"

TABLE 11

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
1/4/54	11:56	02	2	(1) Two runs using same tapes disagreed (2) Read in error	:02	1:23	0
1/5/54	11:46	14	2	(1) Error during reading in caused hang up (2) Machine stopped on O.L.S. reading long tape	:00	:54	0
1/6/54	11:59	:01	1	(1) Chad chute clogged (operator error)	:00	1:26	1
1/7/54	11:59	:01	1	(1) Order changed, reason unknown	:00	:57	0
1/8/54	11:12	:46	1	(1) Double punching	:02	1:46	0
1/11/54	11:07	:50	2	(1) Probably reader error (2) Connection on reader light loose	:03	:29	0
1/12/54	10:51	1:01	3	(1) Unknown, but reading long tapes (2) Unknown, but reading long tapes (3) Unknown, but reading long tapes	:08	:47	0
1/13/54	10:41	1:18	2	(1) Chad box trouble (operator error) (2) 2-14 memory chassis failure (tube in chassis)	:01	1:38	0
1/14/54	11:45	:15	3	(1) Tube (D40) filament burned out (2) Unknown (3) Unknown	:00	:54	0
1/15/54	11:11	:49	3	(1) Spring on reader broken (2) Reading error during DOI (3) Scope output order hand up	:00	:23	0

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
1/18/54	11:59	:01	1	(1) Unknown	:00	:25	0
1/19/54	11:47	:13	2	(1) Scope output failure (2) Reader error during DOI	:00	:25	0
1/20/54	11:04	:53	2	(1) 2^{-14} memory chassis failure (2) Reader error during DOI	:03	:37	0
1/21/54	11:57	:01	1	(1) Double Punching	:02	:28	0
1/22/54	11:18	:42	3	(1) Morning eng. period went past 12:00 (2) Reader error (3) Reader error			
1/25/54	10:13	1:46	2	(1) Morning eng.period went past 12:00 for 2^{-38} memory chassis error (2) Double punching	:01	:27	0
1/26/54	11:49	:11	2	(1) Double punching (2) Error in reading DOI	:00	:53	0
1/27/54	9:30	2:28	1	(1) Morning eng. period went past 12:00	:02	:32	0
1/28/54	11:49	:11	2	(1) Light on reader burned out (2) Reader "B" read two 4's in DOI	:00	:30	0
1/29/54	11:15	:40	2	(1) Leapfrog tape failed to stop at end when read in (2) Stalling of reader on tape	:05	1:48	1
Totals	227:08	12:23	38		:29	17:22	2

at any instant of time and the probability of a failure during any given interval of running time.

The number of interruptions during this month has been very large because of: (1) errors while reading in tapes, (2) errors while punching tapes and, (3) repair times which extended beyond the usual morning periods while attempting to locate the input and output errors. On February 2nd one source of trouble was found which accounted for many of the input errors. It was a broken weld in one of the phototubes which made a connection intermittent under some conditions of vibration. Evidently the reader had to be braking at a certain frequency in order to cause any difficulty. This indicates that the phototube support was probably mechanically resonant at this frequency. Ordinary tapping of the box did not indicate any fault. The difficulty causing the double punching was due to a low output from one of the phototubes in one of the punches. The combined effects of dirt on the glass of the phototube and a particularly old light bulb caused the output voltage from the phototube to be abnormally low. It is believed that these errors have been "permanently" fixed.

VI COMMENTS ON THE MACHINE.

a. Memory

During the month no memory errors occurred which could be associated with the new set of cathode ray tubes in any way at all. A total of 7 memory errors were noted (not all of these occurred during the noon to midnight period and are not,therefore, listed in Table II).

Five of these memory faults were caused because of tube failures in four separate regeneration chassis. One failure was caused because of an abnormally low intensity setting of one of the cathode ray tubes and one was caused because of a tube filament failure in the address generator.

b. Cathode Ray Tube Output

The cathode ray tube output has been used considerably for the first time. The results of computations for the midwest cosmotron have been displayed on the cathode ray tube output. A plot has frequently been made of the height of the accelerated particle from the median plane vs. the radius of the particle for many positions of the particle around its orbit.

VII RESEARCH ON COMPUTER COMPONENT. (Supported in part by ONR Task 24)

a. Magnetic Drum Memory

Some changes were made in the drum circuits to eliminate noise from the playback signal. After this was done, the drum test program showed the circuits would operate without error for periods of an hour, using two tracks. Coaxial cables were installed in place of some unshielded leads between the Illiac and the drum test unit. This eliminated a source of unwanted signals which had been capacitively coupled from other wires and permitted all four tracks on the test unit to be used by a program stored in the Illiac. The operation with all four tracks has not yet been checked for any appreciable length of time.

Damping resistors were added to the heads to eliminate recording

current overshoots. This damping increased the time delay between record and playback of a digit, and made it necessary to change some of the timing pulses to compensate. One timing pulse was rewired so it would not be coupled into the playback amplifier. Lead capacity on the gate into the accumulator was found to be a cause of some oscillations that were also being picked up by the playback amplifier.

A revision of the electrical and logical diagrams associated with the drum has been finished.

b. Computer Transistor Circuits

During this month several new types of transistors were obtained, including four 1858 n-p-n junction transistors which were received on loan from the Bell Telephone Laboratory. These transistors are reported to have a much faster transient characteristic than previous types. Type 200 and 201 n-p-n transistors, and type 102 point-contact transistors were obtained from Texas Instruments Company. The latter type have response times of the order of one or two microseconds and may make practical the use of point-contact transistors with a saturated stable state.

Some response time measurements on type 200 junction transistors have shown response times of the order of eight to ten microseconds.

In order to simplify to some extent the design problem for the junction transistor flip-flop, a program has been written for the Illiac. This program finds various combinations of resistors and supply

voltages which satisfy a set of inequalities and equalities governing the operation of the output amplifier of the flip-flop.

VIII REPORTS AND SEMINARS.

Seminars

Magnetic Core Matrix Memories, by Joseph M. Wier, January 6, 1954.

The α-α Phase Shift Analysis, by J. N. Snyder, January 13, 1954.

Will the Illiac Ever Learn? by Stanley Gill, January 20, 1954.

Internal Reports

#54 by Stanley Gill, REORGANIZATION OF ILLIAC LIBRARY.

#55 by Joseph M. Wier, A DYNAMIC MAGNETIC CORE MEMORY.

Talks

The Development of a Program for an Automatic Digital Computer by Stanley Gill, January 28, 1954 at Louisiana State University.

The Use of Subroutines in Programs by Stanley Gill, January 29, 1954 at Louisiana State University.

IX CONSTRUCTION.

The construction work actively in process consists of work on three new tape readers, the drum circuits and a "final design" cathode ray tube output with camera, fully under the control of the computer (except for removing the film for development).

The work carried out during the month consists of:

1. Two preamplifier chassis were wired for drum.
2. One new photoelectric tape reader has been completed except for final assembly and painting.

3. Chassis parts for two matrix amplifier chassis and one record amplifier chassis have been built.

4. A frame has been built for the cathode ray tube output.

5. The pulsers for the cathode ray tube output have been built.

6. Push button switches for inserting numbers into R_3 from the front panels have been built.

7. A camera for the cathode ray tube output has been partly built.

X PERSONNEL.

The personnel associated with the group and hence the contributors to this report are:

Bateman, Wm. E.
Brown, Mrs. Caroline
Ehrlich, George
Fishel, Jerome (1/2 time)
Gill, Stanley
Golub, Gene (1/2 time)
Gregory, R. T. (1/4 time)
Hardy, H. V.
House, Mrs. Natalie R.
Huffman, W. L.
Jones, W. E.
Kerkering, T. E.
Kudlich, R. A. (RCA Fellow)
Lopeman, H E.
Meagher, R. E.
Michael, G. W.
Miller, R. E. (1/2 time)
Muller, D. E.
Nash, J. P.
Newmark, N. M.(Chairman, Exec.Comm.)
Ogata, Albert I. (Student Assist.)
Polivka, R. P. (1/2 time)
Robertson, J. E.
Russell, Miss Ramona J.
Seinfeld, Robert (Student Assist.)
Seshu, Mrs. Lily (1/2 time)
Shapin, Theodore Jr.
Stephens, Allen
Taub, A. H. (1/2 time)
Wier, J. M.
Yu, Hwa-Nien (1/2 time)

The work of the group is under the administration of an Executive Committee with the following members; N. M. Newmark, Chairman, Stanley Gill, D. E. Muller, J. P. Nash, J. E. Robertson, A. H. Taub and R. E. Meagher.

R. E. Meagher

REM/nrh

UNIVERSITY OF ILLINOIS
GRADUATE COLLEGE
DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

Teaching and graduate research are not, in general, reported herein.

February 1, 1954 - February 28, 1954

I MATHEMATICAL RESEARCH AND CODING.

(This work is supported in part by ONR Task 30).

Logical Algebra. A paper on Boolean algebras in electrical circuit design has been accepted for publication and one is now being prepared on a new type of three-valued logical algebra. Applications of the new algebra to dynamic computer circuits are being explored.

Drum Transfer Routine. A second drum transfer routine is being written. This one utilizes the two unused bits of each order (the instruction digits use only 8 of the 10 bits) to determine a terminating symbol after the address. The tentative plan is to use

11 for the F symbol (fixed address)
10 for the L symbol (relative address)
01 ⎤ for the S symbol (parameters)
00 ⎦

When an S symbol is indicated the routine will refer to another word which holds the information required. Such words will also hold the K (directive) and N(start the program) symbols. The length of the program on the drum will be increased by about one word for every ten S symbols.

Simple Code Testing Scheme. A scheme has been devised, and is about to be tested, to facilitate the trying-out of many short codes. The scheme is intended primarily for use on codes written by students in Math 385.

Features of the scheme are that many tapes can be tested in

one batch, and the operator's work is cut to a minimum, yet the coding is done in a manner differing trivially from ordinary Illiac coding.

An interpretive technique is used, and the cause of stoppage is printed out. If the machine does not stop on OF, a post-mortem similar in principle to Code Cl is automatically applied. Results are identified by having each student punch his name on his tape, and copying this onto the output tape.

Differential Equations. A program for solving systems of ordinary second order differential equations by an iterative method has been written by J. A. Brooks of the Structural Research Laboratory and will be placed in the library. This will be the third library program for ordinary differential equations.

Product Moment Correlations. R. A Twery of the Psychology Department has prepared a program which finds product moment correlations. This program will also be added to the library.

Estimation of Communalities. Further work is being done on speeding up the rate of convergence for the estimation of communalities by the method of maximum likelihood.

Cathode Ray Tube Output. A considerable amount of thought is being given to the use of the cathode ray tube output. Programs for displaying scatter diagrams and for labeling have been prepared in addition to the plotting program already available. The latter should be particularly useful to those groups who are now extensively using the output for plotting solutions to differential equations.

Library Summary Sheets. Summary sheets for library programs are being written for programmers. These summaries, limited when possible to 1 page, contain information necessary for use by a programmer but no details of method.

II MACHINE USE. The following list gives problem specifications for new problems which were tried in February. It does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 266.

NUMBER	PROBLEM SPECIFICATION	AFFILIATION
266	Beta weights for factor estimations	Bur. Ed. Research
267	Quadrimax factor rotation	Bur. Ed. Research
268	Plot scatter diagram	Computer
269	Simultaneous equations (Thesis)	Dairy Science
270	Behavioristic study (Thesis)	Psychology
271	Second order differential eq.	Structural Research
272	Dislocation energy	Physics
273	Simultaneous equations	Structural Research
274	Charge distribution in germanium	Physics
275	Deuteron reaction	Physics
276	Lateral buckling of beams	Structural Research
277	Estimation of factor scores (Thesis)	Bur. Ed. Research
278	Analysis of tracking behavior	Univ. of Indiana
279	Product moment correlation (Thesis)	Psychology

III LIBRARY ROUTINES.

The following two programs were added to the Illiac library during February. The second is by R. F. King.

S3 (130) Logarithm. 14 words.

This program (requiring about 51 milliseconds) is slow but requires little space. It computes $\log_2 x$. Other logarithms can be obtained with conversion factors.

N4 (131) Input a Sequence of Integers. 17 words.

This program reads a sequence of integers from the tape and stores them successively.

Table I shows the distribution of machine time for the month of February.

TABLE I

	h m
Eng. (8-12)	43:15
Eng. (all other times)	19:09
RAR	10:58
Leapfrog	32:32
Wasted	:27

USE OF COMPUTER BY GROUPS

Demonstrations	1:04
Computer Group	20:49
Cosmotron	9:56
Physics	37:42
CSL	38:33
Struct. Research	9:00
Struct. Research (AF24994)	21:02
Struct. Research (NOBS62250)	32:40
Psychology	4:18
Psychology (AF25726)	10:57
Electrical Engineering	2:03
Chemistry	19:51
Agriculture	3:50
Indiana University	1:10
Miscellaneous	5:46
Total:	325:02

IV ERROR FREQUENCY AND ANALYSIS.

The machine is normally used for "engineering" and maintenance between 8 AM and 12 N, and for a check of its performance between 5:00 PM and 5:30 PM of each weekday. Since the periods between 8 in the morning and noon, together with certain other irregular periods like Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more instructive from an error analysis standpoint to look at the periods between noon and midnight of each weekday in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind a summary table has been prepared using the period between noon and midnight of each weekday. This table lists the running time when the machine was operating, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 5:00-5:30 period (when the machine is checked) if no errors are found, the time is given to the "running column". Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented as Table II.

It is important to notice that any interruption of machine time that was not planned for is considered a failure in this table.

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
2/1/54	9:38	2:22	2	(1) Reader error, extra digit read (2) Reader error.	:00	:35	0
2/2/54	11:56	:01	1	(1) Reader error during D.O.I.	:03	:57	0
2/3/54	11:55	:05	1	(1) Reader error during D.O.I.	:00	:37	0
2/4/54	11:54	:04	1	(1) Reader motor stopped.	:02	:22	0
2/5/54	12:00	:00	2	(1) Probably reader error (2) Probably reader error	:00	:20	0
2/8/54	10:52	1:08	1	(1) Reader error due to not stopping properly	:00	:40	0
2/9/54	11:58	:01	1	(1) Printer error	:01	:25	0
2/10/54	11:11	:49	1	(1) Printer error	:00	:31	0
2/11/54	11:42	:17	1	(1) Tube failure at $2^{-21}R_1$	:01	:42	0
2/12/54	11:19	:39	3	(1) Leapfrog failure. Tube not completely in. (2) Two of phosphor bronze wires in decoding chassis too close together. (3) Punch error or machine error	:02	:47	1
2/15/54	8:28	3:32	3	(1) Memory error 0 to 1 all locations of position 31 (2) Unknown (3) Probably reader error	:00	:47	1

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
2/16/54	10:32	1:28	3	(1) Unknown, two runs gave different results (2) Unknown (3) Mult. test failure in Leapfrog	:00	:31	1
2/17/54	8:28	3:32	2	(1) Multiplication test failure, cause unknown (2) Probably reader error	:00	:41	0
2/18/54	11:20	:40	1	(1) Run over from morning engineering	:00	:41	0
2/19/54	11:59	:01	1	(1) Probably a reader error	:00	:17	0
2/22/54	10:35	1:25	3	(1) Error in L.F. sum check (2) L.F. failure pos. 25 add 2F3 1→0 (3) Probably reader error	:00	:29	2
2/23/54	11:05	:55	2	(1) Scope output would not work because of power supply failure (2) Pos. 25 add 2F3 1→0 Bad Cathode ray tube	:00	:20	1
2/24/54	12:00	:00	0		:00	:26	0
2/25/54	12:00	:00	0		:00	:00	0
2/26/54	11:42	:16	1	(1) Reader may have skipped a character.	:02	:32	0
TOTALS	222:34	17:15	30		:11	11:05	7

In rare cases where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This overall system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" at any instant of time and the probability of a failure during any given interal of running time.

The error analysis for February shows that a number of errors are still due to the reading of tapes. It is believed that most of these errors have occurred because of improper stopping of the tape. Some changes in both the logic concerning the reading of tapes and the mechanical parts of the tape readers are contemplated.

V COMMENTS ON THE MACHINE.

a. Memory

During the month several errors have been associated with the memory. In some cases the errors resulted from tube failures within the regeneration chassis but in two cases it became necessary to change cathode ray tubes. In one case the cathode ray tube appeared to have a loose second anode connection. In the other case a flaw on the surface of the phosphor became of sufficient amplitude to require changing the tube. This is the first flaw on this set of tubes. It evidently increased with use of the tube because originally it was too small to be noted.

b. Teletype Equipment

Two Teletype printers in the tape room have been modified so

that 26 characters can be printed according to the "final" tape code. A third printer is in the process of being modified and is nearly finished.

c. Engineering Codes

Two new engineering codes have been added to the list already available. The first (number 31) will make possible the reperforation of tapes from the Illiac. The second is a program to put a test pattern on the cathode ray tube output in order to check for deflection linearity.

VI RESEARCH ON COMPUTER COMPONENTS. (This work is supported in part by ONR Task 24).

a. Magnetic Drum Memory

Tests have shown that all four drum tracks in the temporary unit will not operate properly with the Illiac. Using all four tracks involves switching the preamplifiers. Previous use of two tracks involved switching only the main amplifiers. The coincidence signal was delayed an additional word time with the thought of allowing switching voltages ample time to settle down. This made only a slight improvement. This trouble is being investigated further. Some corrections have been made in the playback amplifier circuit.

b. Computer Transistor Circuits

The fast-response junction transistors (1858) have been tested in the flip-flop circuit. No significant improvement in triggering time was obtained, leading to the conclusion that the delay is not primarily a collector hole-storage effect. Instead,

most of the triggering time is used to reduce the base current to the conducting transistor. The base current is required to be a minimum value for the worst transistors, and therefore this current will be excessive for normal or better-than-average transistors. Two possible modifications of the circuit were tried, but there were other objections to both.

Investigations have been made into the possibility of using either point-contact transistors or hook-collector junction transistors for a flip-flop type circuit. The point-contact transistors would be used in a saturating type circuit, similar to the one described in Internal Report 48. The hook-collector device would be used in a symmetrical type of trigger circuit. On the basis of these calculations, it has been decided to concentrate upon a type of circuitry using point-contact transistors in the flip-flops, and junction transistors for gates, output amplifiers, and logical circuitry.

c. Design of a Small Magnetic Core Memory

At the request of the Control Systems Laboratory, we have undertaken the design of a small magnetic core memory. This memory is to have a capacity of 64 words each of 30 binary digits. The access time requirements are such that it is necessary to be able to store a 30 bit word in 300 microseconds or to read out 1 bit in 300 microseconds. Drawings for all of the circuits have been prepared in rough form and are now waiting to be drafted. The circuits require a total of 619 vacuum tubes and a total power (ac and dc) amounting to 3,700 watts. It has been estimated that

the memory will require a cabinet of about 6' x 4' x 2'. Certain special provisions and a brief explanation of how the memory is arranged are presented in the following paragraphs.

Since it is required that the unit be able to store within 600 µsec after a given request, and since the reading out of a word proceeds at no more than one digit per 300 µsec, it is necessary to provide for storing interlaced between the reading out of the individual digits of a word. The memory control is a clock driven device in which a set of 10 pulsers are triggered every 60 µsec. Only one pulse in the cycle changes the operation to be done next and nothing at all happens if there is no request that anything be done. By suitably interrupting the cycle, one of several operating states may be achieved. These are:

1. Do nothing,
2. Read out the next digit,
3. Write in a word with no other operation at hand,
4. Write in a word and remember to go back to the same part of the read cycle to pick up the reading of the word currently in the process of being read.

Any one may be done in one 60 µsec period. In any case of doubt, writing shall take preference over reading.

To write in a word:

1. Gate the address of the storage position to a buffer register. This address is 1 greater than the previous write storage address.

2. Apply + I/3 to all 30 columns of the 64 x 30 matrix.

3. Apply + 2I/3 to the word dictated by the write address.

4. Turn off the + 2I/3 current; cores in the word are now all at + B remanent.

5. Set the column drivers to apply + I/3 to columns into which it is desired to write a "0", - I/3 to columns into which it is desired to write a "1".

6. Apply - 2I/3 to the selected word.

7. Gate buffer address to write address, increased by 1.

To read a word:

1. Gate the read address of the position to be read from the read address register to the buffer register. This address is one greater than previous read address.

2. Set 6 of the column drivers to + I/3, the remainder at - I/3.

3. Apply + 2I/3 to the selected word. All cores with I/3 + 2I/3 = I applied will be sensed for their contents. This information is sensed by amplifying these signals with 6 amplifiers and amplitude strobing the output, the information being temporarily placed in 6 flip-flops. Then turn off the + 2I/3.

4. When the request to read out a digit arrives, present one of the 6 stored bits to the outside and then afterwards increase a scale of six counter which indicates which of the six is to be read.

5. Repeat 4 until all six digits are read and then repeat 3 to obtain the next set of 6 digits of the word out of the cores.

6. Repeat 4, reading out all of the new set of 6 digits.

7. Do 4, 5, and 6 until all digits of the word have been read out.

8. Gate buffer address to read address register, increasing it by one.

Writing is interlaced with reading by writing in one of the unused 60 μsec periods between the reading out of one digit. Since the digit demand rate is never to exceed 3000 cycles per second, several unused 60 μsec periods exist between each readout of a digit.

The circuit details are taken care of by more or less standard digital computer techniques. There is a bit of variance from Illiac circuitry where much larger signals are required than the standard +0v, - 37v flip-flop voltages but these are done with an eye to making circuits safe with ± 10% resistor variations and ± 5% power supply variations. The current demands for driving the cores, which is quite high for short periods but has a low average value, is taken care of by using an RC filter of long time constant (connected to the +300v. supply) for the supply voltage for most of the core drivers. This practice has resulted in somewhat more elaborate demands on the other circuitry and has made it necessary to add a considerable number of tubes but the overall power dissipation is somewhat lower.

VII REPORTS AND SEMINARS.

Seminars

A description of the Logical Design of a Medium Speed Computer at the Central Laboratory of the Netherlands Postal and Telecommunications Services, by Theodore Shapin, Jr., February 17, 1954.

A Three-Valued Logical Algebra Which is Invariant Under a Wide Class of Transformations, by David E. Muller, February 24, 1954.

Talks

"Some Single-Address Machines" by Stanley Gill, February 5, 1954 at Oak Ridge National Laboratory.

VIII CONSTRUCTION. The shop has completed the construction of the cathode ray tube output unit with its camera. Of course, detailed tests of it still need to be made before it can be put into use.

IX PERSONNEL. The personnel associated with the group and hence the contributors to this report are:

Bateman, Wm. E.
Brown, Mrs. Caroline
Carter, Clifford E. (Started 3/1/54)
Ehrlich, George
Fishel, Jerome (1/2 time)
Gill, Stanley
Golub, Gene (1/2 time)
Gregory, R. T. (1/4 time)
House, Mrs. Natalie R.
Huffman, W. L.
Jones, W. E.
Kerkering, T. E.
Kudlich, R. A. (RCA Fellow)
Lopeman, H. E.
Meagher, R. E.
Michael, G. W.
Miller, R. E. (1/2 time)
Muerle, John (1/2 time)
Muller, D. E.
Nash, J. P.
Newmark, N M. (Chairman, Executive Committee)

Ogata, Albert I., (Student Assistant)
Polivka, R. P. (1/2 time)
Robertson, J. E.
Russell, Miss Ramona J.
Seinfeld, Robert (Student Assistant)
Seshu, Mrs. Lily (1/2 time)
Shapin, Theodore Jr.
Stephens, Allen
Taub, A. H. (On Sabbatical Leave)
Wier, J. M.
Yu, Hwa-Nien (1/2 time)

The work of the group is under the administration of an Executive Committee with the following members; N. M. Newmark, Chairman, Stanley Gill, D. E. Muller, J. P. Nash, J. E. Robertson, A. H. Taub and R. E. Meagher.

R. E. Meagher.

REM/nrh

UNIVERSITY OF ILLINOIS

GRADUATE COLLEGE

DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

Teaching and graduate research are
not, in general, reported herein.

March 1, 1954 - March 31, 1954

I MATHEMATICAL RESEARCH AND CODING. (This work is supported in part by ONR Task 30).

Logical Algebra. A paper on three-valued logic has been sent off for publication.

Drum Transfer Routine. A drum playback routine has been prepared in which every sixth word contains the ten terminating symbols required for the following five words. Each terminating symbol is designated as a four bit number as follows:

0 represents the symbol F,

1 represents the symbol L,

2 represents a constant,

3 to L represent S3 to SL.

The routine is entered as a closed subroutine with the left address of the standard entry containing the first Williams location. Williams locations 0 and 1 must contain the length of the routine and its location, respectively.

Simple Code Testing Scheme (SCOT). This scheme, outlined in the February report, has been completed and found to be highly successful. It came into use on March 29, and in the 3-day period March 29-31 six computer runs were made, totalling 32 minutes of machine time. In that time, 35 programs prepared by the students of Mathematics 385 were tested. The scheme is now available to all machine users and thought is being given to a more powerful program of the same kind.

Oscilloscope Output. A program is being prepared which will make it possible to use print routines with the oscilloscope as well as in the usual way.

II LIBRARY ROUTINES.

During March one program was added to the Illiac library:

P10 (133)	Print Headings Interlude. 8 words. This program, placed ahead of other programs, makes it possible to print column headings and other material needed only once. It is then overwritten.

III MACHINE USE.

The following list gives problem specifications for new problems which were tried in March. It does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 280.

NUMBER	PROBLEM SPECIFICATION	AFFILIATION
280	Simple Code Testing Scheme	Computer
281	Shock wave response	Structural Research
282	Target thickness computation	Physics
283	Quadrimax factor rotation	Psychology
284	Space-charge flow in a parallel plane triode	Elect. Engineering
285	Stresses in pressure vessels	Computer
286	Matrix multiplication	Structural Research
287	Matrix inversion	Structural Research
288	Illumination line to plane (Thesis)	Elect. Engineering

NUMBER	PROBLEM SPECIFICATION	AFFILIATION
289	Product moment correlations, variance, covariance, etc.	Psychology and Computer
290	Multiple correlation coefficients	Psychology
291	Matrix calculations	Inst. Comm. Res.
292	Asymptotic series	Elect. Engineering
293	Evaluation of determinants	Agronomy

Table I shows the distribution of machine time for the month of March.

TABLE I

	h m
Eng. (8-12)	62:55
Eng. (all other times)	29:28
RAR	11:36
Leapfrog	36:08
Wasted	:22
USE OF COMPUTER BY GROUPS	
Demonstrations	10:02
Computer Group	10:49
Cosmotron	13:46
Physics	34:03
CSL	54:20
Struct. Res.	11:39
Struct. Res. (AF24994)	45:01
Psychology	3:56
Psychology (AF25726)	8:03
Elect. Engineering	10:26
Chemistry	18:41
Agriculture	4:24
Indiana University	3:14
Miscellaneous	1:20
	381:49

IV ERROR FREQUENCY AND ANALYSIS. The machine is normally used for "engineering" and maintenance between 8 AM and 12 N, and for a check of its performance between 5:00 PM and 5:30 PM of each weekday. Since the periods between 8 in the morning and noon, together with certain other irregular periods like Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more instructive from an error analysis standpoint to look at the periods between noon and midnight of each weekday in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind a summary table has been prepared using the period between noon and midnight of each weekday. This table lists the running time when the machine was operating, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 5:00-5:30 period (when the machine is checked) if no errors are found, the time is given to the "running column". Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented as Table II.

It is important to notice that any interruption of machine time that was not planned for is considered a failure in this table.

TABLE II

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
3/1/54	11:33	:27	2	(1) Unknown kind of error. (2) Memory Failure G.P. Short V16 - address generator.	:00	:57	0
3/2/54	12:00	:00	0		:00	1:42	0
3/3/54	11:52	:08	1	(1) Address 17F was erroneously cleared to 0.	:00	:54	0
3/4/54	11:50	:09	3	(1) Unknown (2) Reader error (3) Reader error	:01	:45	0
3/5/54	10:11	1:47	7	(1) Leapfrog. Read a 4 incorrectly. (2) Two different results on same tape. (3) Power supply went off. (4) Probably memory error. (5) -300v 3 phase circuit breaker opened. (6) +150v fuse blew. No explanation. (7) Two different results on same tapes.	:02	:46	2
3/8/54	12:00	:00	0		:00	:19	0
3/9/54	11:35	:21	1	(1) Fuse blew. +300v memory circuit no. 23	:04	:41	0
3/10/54	12:00	:00	0		:00	:47	0
3/11/54	11:59	:01	1	(1) Error during read-in.	:00	:27	0

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
3/12/54	10:19	1:41	3	(1) Read an "F" twice (2) Reader error (3) Reader error	:00	:22	0
3/15/54	11:57	:00	0		:03	:27	0
3/16/54	11:52	:06	1	(1) Punch clogged.	:02	:36	0
3/17/54	11:17	:43	2	(1) Reader error. (2) Reader skipped a character.	:00	:01	1
3/18/54	12:00	:00	0		:00	:32	0
3/19/54	11:40	:20	1	(1) Reader error suspected.	:00	:23	0
3/22/54	11:20	:37	3	(1) Two different results on same tapes. (2) Two different results on same tapes. (3) Punch error.	:03	:35	0
3/23/54	8:58	3:02	4	(1) Memory 2^{-35} $0 \rightarrow 1$ at all locations. (2) Reader error. (3) Reader error. (4) Reader error.	:00	:24	2
3/24/54	7:14	4:46	6	(1) Memory error. 2^{-37} $0 \rightarrow 1$ location 0 (2) Two different results on same tapes. (3) Two different results on same tapes. (4) Two different results on same tapes. (5) Memory error $0 \rightarrow 1$ pos. 2^{-1}	:00	:20	0

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
				(6) Unknown			
3/25/54	11:47	:13	1	(1) Tape failed to stop when it came to end. (Leapfrog)	:00	:40	1
3/26/54	9:09	2:49	3	(1) Two different results on same tape. (2) Unknown (3) Reader error.	:02	:32	0
3/29/54	7:27	4:33	6	(1) Reader reads spaces as L's. (2) Reader error. (3) Unknown, possibly reader. (4) Reader error. (Shorted tube, V15 chassis U cath.-filament) (5) Leapfrog failure 2^{-37} $0 \rightarrow 1$ (6) Fuse in circuit no. 23 blew.	:00	:09	1
3/30/54	12:00	:00	0		:00	:25	0
3/31/54	11:59	:01	1	(1) Unknown.	:00	:00	0
TOTALS	253:59	21:44	46		:17	13:09	7

In rare cases where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This overall system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" at any instant of time and the probability of a failure during any given interval of running time.

Again, just as in the previous month's report, the number of reader errors is very high. Although a number of the errors could be defined precisely as reading a space as an L or reading a character twice it has not been possible to say with certainty what caused the erroneous readings. Several minor but important changes have been made to increase the tolerance range of acceptable reader performance.

V COMMENTS ON THE MACHINE.

a. Memory

Several errors have been due to the memory during the month, but in each case the difficulty was usually explained by the failure of a small tube. It was not necessary to change any cathode ray tube during the month.

b. Teletype Equipment

All teletype printers have been altered so that letter characters can now be printed from any printer according to the tape code in the Illiac Programming book on page 9-5.

c. New Input Logic

A new design for the input logic has been finished. This new logic separates the operations of reading from the tape and

starting and stopping the tape. By doing this, the braking time allowed to stop the tape can be increased. Although the circuits for this logic have been built they have not been incorporated in the machine. The drawing numbers are M568 and M569.

d. Cathode Ray Tube Output

The new cathode ray tube unit has been finished and put into operation. There is some "barrel-shaped" distortion in the pattern recorded on the film. The reason for this is being investigated.

e. Tape Preparation Equipment

The logical design and the circuits for a photoelectric tape comparer have been prepared. The logical design for a photoelectric reader-high speed punch reperforator system has been completed.

VI RESEARCH ON COMPUTER COMPONENTS. (This work is supported in part by ONR Task 24).

a. Magnetic Drum Memory

All of the basic drum circuits have been built and have been in a state of test for several months. As reported earlier, four drum tracks are connected to the present circuits. A number of "small" difficulties have been noted and corrected in the past and brief periods of error free operation (10-20 minutes) have been obtained.

During this month some additional improvements have been made including: 1) a correction of a logical error which permitted an indication of address coincidence inaccurately under some conditions, 2) an improvement in the address cathode follower connections in the

Illiac to improve their transient response, 3) a reduction in "main" amplifier gain in order to help improve switching transients, and 4) a reduction of switching noise introduced in the preamplifiers.

After these changes it appears that it is possible to operate the drum on test routines of "random" numbers without error for indefinite periods (5 hours) without an error in recording or playback on the four tracks, provided that selection is carried out on every 16th word. However, if the selection is carried out on every 8th word, errors result in about 10-20 minutes. There is evidence that the errors which occur when selecting every 8th word can be said to be due to one or more of the following:

1. switching transients in the circuits,
2. magnetic surface irregularities,
3. pulse "noise" which gets into the amplifiers but should not do so, and
4. differences from one head to another.

A study is now being made of these four items and the Illiac and the drum are used together for this purpose about one hour each day.

b. Computer Transistor Circuits

During the month tests were made on response times of the type 102 point-contact transistors. The results of these tests were as follows:

1. The fall time after cutting off the transistor does not depend upon the length of time in saturation.

2. The fall time increases with load resistance for constant emitter current and power supply voltage.

3. The fall time increases with emitter current after emitter saturation current has been reached.

4. In order to minimize the fall time, with given conditions for the saturation state, it is necessary to drive the emitter more negative than the zero-emitter current intercept of the region III (saturation) input characteristic.

The design requirements for the point-contact transistor flip-flop have been worked out. A set of parameters has been obtained which satisfy these requirements, and a flip-flop circuit was constructed.

This circuit was tested for all combinations of ten transistors, for each of two sets of ten transistors. One transistor had very low current-gain, and two had excessively small collector resistances. With the exception of these, all combinations of transistors tested worked satisfactorily in the circuit.

The design of gating and read-out circuits, and of logical circuitry is now being carried out.

c. Design of Small Core Memory for CSL

The design of this memory, including some necessary changes, is now complete and the drawings are being prepared and printed. The cores for the memory have been received. Some construction on the memory, it is hoped, will be started about May 1.

VII REPORTS AND SEMINARS.

Seminars

Logical Organization of Serial Computers, by J. E. Robertson, March 3, 1954.

Some Problems in the Design of Two Transistor Flip-flops by R. A. Kudlich, March 10, 1954.

A Code for Linear Programming, by Leonard M. Isaacson, March 17, 1954.

A Multiple Correlation Analysis on the Illiac as Applied to an Agronomic Problem, by R. H. Rust, March 24, 1954.

Direct-Coupled Flip-flop Circuit with Point Contact Transistors, by R. A. Kudlich, March 31, 1954.

VIII CONSTRUCTION

The following construction work has been carried out in the shop:

1. Two matrix amplifier chassis (drawing M551) have been built for the drum memory.

2. One record amplifier chassis (drawing M550) has been built for the drum memory.

3. The camera for the cathode tube output has been finished.

4. Some parts for two additional photoelectric tape readers have been constructed.

5. New photoelectric reader control (drawing M568) and counter selection chassis (drawing M569) have been partially completed.

IX PERSONNEL. The personnel associated with the group and hence the contributors to this report are:

Bateman, Wm. E.
Brown, Mrs. Caroline
Carter, Clifford E.

Clements, Virgil F. (Starting 4/6/54)
Ehrlich, George
Fishel, Jerome (1/2 time)
Gill, Stanley
Golub, Gene (1/2 time)
Gregory, R. T. (1/4 time)
House, Mrs. Natalie R. (Term. 4/9/54)
Huffman, W. L.
Jones, W. E. (Term. 5/13/54)
Kerkering, T. E.
Kudlich, R. A. (RCA Fellow)
Lopeman, H. E.
Meagher, R. E.
Michael, G. W.
Miller, R. E. (1/2 time)
Muerle, John (1/2 time)
Muller, D. E.
Nash, J. P.
Newmark, N. M. (Chairman, Executive Committee)
Ogata, Albert I. (Student Assistant)
Polivka, R. P. (1/2 time)
Robertson, J. E.
Russell, Miss Ramona J.
Seinfeld, Robert (Student Assistant)
Seshu, Mrs. Lily (1/2 time)
Shapin, Theodore Jr.
Stephens, Allen
Taub, A. H. (On Sabbatical Leave)
Wier, J. M.
Yu, Hwa-Nien (1/2 time)

The work of the group is under the administration of an Executive Committee with the following members: N. M. Newmark, Chairman, Stanley Gill, D. E. Muller, J. P. Nash, J. E. Robertson, A. H. Taub and R. E. Meagher.

R. E. Meagher.

REM/pmp

UNIVERSITY OF ILLINOIS

GRADUATE COLLEGE
DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

Teaching and graduate research are
not, in general, reported herein.

April 1, 1954 - April 30, 1954

I MATHEMATICAL RESEARCH AND PROGRAMMING. (This work is supported in part by ONR Task 30).

Complex Numbers. A floating decimal routine for complex numbers with essentially the same order code as library routine A1 has been prepared. It handles complex numbers which are held in floating decimal form in two memory locations. Three auxiliary routines have been prepared for use with the complex numbers routine:

a. Complex conjugate,
b. Modulus,
c. Square root (principal value).

Solution of Algebraic Equations. The complex numbers routine has been used to solve algebraic equations with complex coefficients. The largest such equation which has been tried is a polynomial of the 50th degree. The solution required about ten minutes.

Determinantal Equation. $|A-\lambda B| = 0$. A complete program making use of library routine M3 will solve the above equation when A and B are symmetric and B is positive definite.

Display Interpreting Program. This program will make any print routine useful as a display routine for the cathode ray tube output. It uses a blocking technique rather than being interpretive.

Drum Transfer Routines. The drum transfer routines described last month have been tested and work properly. A second routine which packs words more efficiently (but which is slower) is now being written.

II LIBRARY ROUTINES. During April the following two programs were added to the Illiac library:

W2 (134)	Word Sorting According to an Ordering Relation. 25 words. This program sorts consecutive words in the memory by starting at the top of the list, comparing the first two, and interchanging if necessary; then taking the second and third and if these are interchanged going back to the first and the new second, etc. Instructions for determining the order of sorting are at the end of the program and can be conveniently changed.

K2 (135) Product Moment Correlations, Means, Standard Deviations, Variances and Covariances. Entire Program. The program uses four parameters: sample size, number of variables, number of answer decimals for correlation matrix, and number of answer decimals for the other results (if desired). There is a limit of 38 variables but no limit to the number of observations.

III AUXILIARY LIBRARY. There are many programs prepared for the Illiac which are useful to persons other than the programmer, but which are not of general enough interest to warrant their inclusion in the Illiac library. With the aid of Illiac users an auxiliary library is being established so that programs of special interest will be readily available for reference. These will be described in the same way as library routines and Illiac users will be able to take advantage of work done by others on problems similar to their own.

IV MACHINE USE. The following list gives problem specifications for new problems which were tried in April. It does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 294.

NUMBER	PROBLEM SPECIFICATION	AFFILIATION
294	Epinephrine experiment	Dairy Science
295	Quadrimax calculation	Psychology
296	Latent roots and vectors	Psychology
297	Linear program	Ag. Economics
298	Matrix inversion	Psychology
299	Complex matrix algebra	Computer
300	Ionic species calculation	Chemistry
301	Job-knowledge tests	Psychology
302	Electron energies in a simple metal model	Physics
303	Laplace's equation in cylindrical coordinates	Physics

NUMBER	PROBLEM SPECIFICATION	AFFILIATION
304	Maximum likelihood factor analysis	Psychology
305	Indices of factorial similarity	Psychology
306	Nonlinear simultaneous equations	Purdue Univ.
307	Roots of a polynomial	Computer
308	Latent roots and vectors	Univ. of N.C.
309	Rise time and overshoot of series peaking circuit	Elect. Eng.
310	Solution of integrals	Computer
311	Irreducible polynomials in the field modulo 29	Computer
312	Solution of determinantal equation $\|A-\lambda B\| = 0$.	Computer

Table I shows the distribution of machine time for the month of April.

TABLE I

	h:m
Eng. (8-12)	60:04
Eng. (All other times	29:01
RAR	12:57
Leapfrog	30:35
Wasted	:40

USE OF COMPUTER BY GROUPS

Demonstrations	3:58
Computer Group	14:50
Classes	2:56
Cosmotron	16:11
Physics	19:28
CSL	59:52
Struct. Res.	23:51
Struct. Res. (AF 24994)	33:18
Psychology	2:41
Psychology (Af 25726A)	5:33
Elect. Engineering	23:34
Chemistry	30:14
Agriculture	4:33
Public Health (3M9020C3)	3:49
Indiana University	4:10
Miscellaneous	9:52
	392:07

V ERROR FREQUENCY AND ANALYSIS. The machine is normally used for "engineering" and maintenance between 8:00 A.M. and 12:00 N, and for a check of its performance between 5:00 P.M. and 5:30 P.M. of each weekday. Since the periods between 8:00 in the morning and noon, together with certain other irregular periods like Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more instructive from an error analysis standpoint to look at the periods between noon and midnight of each weekday in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind a summary table has been prepared using the period between noon and midnight of each weekday. This table lists the running time when the machine was operating, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 5:00-5:30 period (when the machine is checked) if no errors are found, the time is given to the "running column." Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented as Table II.

It is important to notice that any interruption of machine time that was not planned for is considered a failure in this table. In rare cases where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This overall system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" at any instant of time and the probability of a failure during any given interval of running time.

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
4/1/54	11:51	:01	1	(1) Unexplained	:08	:27	0
4/2/54	5:39	6:21	6	(1) Reader B error due to broken connection (2) Reader error or memory error (3) Unexplained error (4) Unexplained error (5) Unexplained error (6) Grid-plate short in Row 3 2^{-29} of adder	:00	:53	1
4/5/54	11:51	:07	2	(1) Reader B read an extra "0" (2) Reader B read a space as a 7.	:02	:37	0
4/6/54	11:58	:02	2	(1) Reader C error. (2) Two different results from same tape.	:00	:32	0
4/7/54	11:08	:50	5	(1) L3 was F2 in decoding chassis. (2) Punch 1 error. Leapfrog. (3) Two different results on same tapes (DOI hang-up) (4) Two different results on same tape. (5) Two different results on same tape.	:02	:23	2
4/8/54	11:57	:03	1	(1) Fuse blew in 150v circuit no. 5.	:00	:34	0
4/9/54	11:34	:22	5	(1) Punch no. 2 failed to punch "0's" with switch. (2) Punch no. 1 punching double characters. (3) Reader B read extra "0." (4) Punch no. 2 punched two extra zeros. (5) Punch no. 2 punched extra "0"	:04	:30	0

DATE	RUNNING OK TIME	REPAIR TIME	TIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
4/12/54	11:58	:00	0		:02	:23	0
4/13/54	11:58	:00	0		:02	:32	0
4/14/54	11:17	:43	2	(1) Two different results with same tape. (2) Memory chassis pos. 12 error	:00	:24	1
4/15/54	11:57	:03	3	(1) Two different results with same tape. (2) Two different results with same tape. (3) Two different results with same tape.	:00	:23	0
4/16/54	11:57	:00	0		:03	:29	0
4/19/54	11:58	:00	0		:02	:23	0
4/20/54	11:56	:00	0		:04	:27	0
4/21/54	11:01	:59	7	(1) Two different results from same tape. (2) Stopped on DOI read-in. (3) Two different results from same tape. (4) Stopped on DOI read-in. (5) Two different results from same tape. (6) Two different results from same tape. (7) Two different results from same tape.	:00	:20	
4/22/54	12:00	:00	0		:00	:31	0
4/23/54	11:58	:00	0		:02	:38	0
4/26/54	9:41	2:19	4	(1) Punch no. 1 punched extra 5 holes. (2) Two different results from same tape. (3) Reader C read an extra "O" in DOI. (4) Memory error pos. no. 13 chassis replaced because of an open filament.	:00	:28	0

DATE	RUNNING OK TIME	REPAIR TIME	TIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
4/27/54	12:00	:00	0		:00	:23	0
4/28/54	12:00	:00	0		:00	:27	0
4/29/54	11:34	:26	1	(1) Reader C skipped a one.	:00	:19	0
4/30/54	11:58	:02	2	(1) Punch no. 1 punched a double 8. (2) Punch no. 1 punched a double 8 and a double 5.	:00	2:23	0
TOTALS	251:12	12:17	11		0:31	12:26	4

VI COMMENTS ON THE MACHINE.

a. Memory

During this month, several failures occurred which were associated with the memory but all of them were associated with tube failures in regeneration chassis. No cathode ray tubes were changed during the month. It is now seldom necessary to adjust any of the memory controls when the machine is turned on each morning. The intensity of perhaps two or three tubes may be adjusted slightly once each week. The read-around ratio performance of the machine remains in excess of 250 at all spots.

b. Cathode Ray Tube Output

Because no 5" cathode ray tube was found which had both good focus properties and good deflection linearities, the cathode ray tube output unit was changed to use a 3KP1 as the cathode ray tube to be photographed. At the same time, the lens was changed to keep the size of the image on the film approximately the same as that obtained with a 5" tube.

In order to judge the linearity and the precision of this display unit, a geometrical pattern of straight lines has been displayed and photographed on 35 mm film. When this film is projected in a Recordak microfilm reader the following statements concerning the display can be made:

(1) Straight lines are reproduced as curved lines (at the edges of the pattern) such that the sagitta of the arc is less than 0.3% of the length of the line.

(2) Vertical lines deviate from perpendicularity with respect to horizontal lines by less than 0.65 degree.

(3) Linearity of deflection from one part of the tube face to another is such that for two spots with digital coordinates (x,y_1) and (x,y_2), the displayed analogue coordinates (X_1,Y_1) and (X_2,Y_2) are

$$\left|(X_2-X_1)\right| < 0.007\left(\frac{X_2+X_1}{2}\right) \text{ for any } y_1 \text{ and any } y_2$$

Similarly for two spots with digital coordinates (x_1,y) and (x_2,y), the displayed analogue coordinates (X_1,Y_1) and (X_2,Y_2) are

$$\left|(Y_2-Y_1)\right| < 0.007\left(\frac{Y_2+Y_1}{2}\right) \text{for any } x_1 \text{ and } x_2$$

(4) The X and Y deflection sensitivites agree to with 0.7 percent.

(5) The extent of the drift of the pattern with time with or without using the scope is small but unknown.

The shutter originally built with the camera failed and has subsequently not been in use. Although shutter orders for the machine are still being obeyed, the present camera arrangement allows the shutter to be open at all times.

VII RESEARCH ON COMPUTER COMPONENTS. (This work is supported in part by ONR Task 24.)

a. Magnetic Drum Memory

Tests are still being made to determine the cause of errors while using the drum with the Illiac. These tests have shown that the errors are due to one or more of the following items:

1. A limited signal-noise ratio of the signal from the drum heads due in part to flaws in the magnetic coating of the drum.
2. Switching transients introduced when the address of a drum operation is changed just prior to reading a word.
3. Noise introduced because of inadequate shielding in some of the drum head pick-up wires used in the experimental unit.
4. Faulty operation of the word counter.

Recent tests have shown that the signal-noise ratio could be very much improved if the drum were recoated with a thicker layer of iron oxide.

b. Computer Transistor Circuits

During this month, the major effort of the transistor work has been concentrated on the design of gating circuitry and logic circuits for use with the flipflop circuit designed previously.

The equations for both "and" and "or" circuits have been worked out. The designs for these two circuits differ only in the polarity of the junction transistors used. That is, for a given logic convention, e.g. "zeros" more positive than "ones," a multiple

input circuit involving several pnp transistors with their emitters tied to a common load resistor will form an "or" circuit, whereas several npn transistors connected in the same manner will form an "and" circuit.

This same useful characteristic is applicable also to "and not" and "or not" circuits. Here a common collector load resistance is used. The design is complicated by the change in dc level from input to this collector load, necessitating a resistance bleeder or other means of restoring the proper dc values. In addition, it is necessary to allow for sufficient collector swing, with variations in signal levels, to prevent saturation of the transistor. The design problem can be very much simplified by using a Zener diode to change the dc levels in the same manner a gas voltage-regulator tube can be used in vacuum tube circuitry.

The design of the gating transistor for the flipflop must take into account that the flipflop gating point must be pulled below the normal signal levels in the logical circuitry, so that here again a shift in dc levels is required. This circuit has been worked out using a conventional bleeder resistance. It will also be considered with the Zener diode method of shifting dc level.

It is also planned to study the design of diode-type logic circuitry. This offers important advantages in simplicity and perhaps reliability, but there appear to be certain limitations on the manner in which such circuitry can be connected.

c. Design of a Small Magnetic Core Memory

The small magnetic core memory designed as a buffer storage system for the Control Systems Laboratory has been completed except for the final preparation of several drawings.

VIII REPORTS AND SEMINARS.

Seminars

Direct-coupled Flipflip Circuit with Point Contact and Junction Transistors, by R. A. Kudlich, April 7, 1954.

Comments on Organization of Structural Mechanics Problems for Solution on the Illiac, by John Brooks, April 14, 1954.

The Maximum Likelihood Method of Factor Analysis, by Gene H. Golub, April 28, 1954.

IX CONSTRUCTION. The shop has carried out the following construction work:

1. Two new photo-electric tape reader units have been partly constructed.
2. Construction work on the cathode ray tube output unit was completed.
3. The machining of selector bars for full Teletype keyboards for some of the older Teletype units has been started.
4. A new photo-electric tape reader control was built according to drawing M-568.

X PERSONNEL. The personnel associated with the group and hence the contributors to this report are:

Bateman, Wm. E.
Brown, Mrs. Caroline (3/4 time)
Carter, Clifford E.
Clements, Virgil F. (Started 4/6/54)
Courter, Mrs. Helen (Started 4/28/54)
Ehrlich, George
Fishel, Jerome (1/2 time)
Gill, Stanley
Golub, Gene (1/2 time)
Gregory, R. T. (1/4 time)
Huffman, W. L.
Jones, W. E. (Term. 5/13/54)
Kerkering, T. E.
Kudlich. R. A. (RCA Fellow)
Lopeman, H. E.
Meagher, R. E.
Michael, G. W.
Miller, R. E. (1/2 time)
Muerle, John (1/2 time)
Muller, D. E.
Nash, J. P.

Newmark, N. M. (Chairman, Executive Committee)
Ogata, Albert I. (Student Assistant)
Pennell, Mrs. Phyllis (Temporary and part-time)
Polivka, R. P. (1/2 time)
Robertson, J. E.
Russell, Miss Ramona J.
Seinfeld, Robert (Student Assistant)
Seshu, Mrs. Lily (1/2 time)
Shapin, Theodore Jr.
Stephens, Allen
Taub, A. H. (On Sabbatical Leave)
Wier, J. M.
Yu, Hwa-Nien (1/2 time)

The work of the group is under the administration of an Executive Committee with the following members: N. M. Newmark, Chairman, Stanley Gill, D. E. Muller, J. P. Nash, J. E. Robertson, A. H. Taub, and R. E. Meagher.

R. E. Meagher

REM/hc

UNIVERSITY OF ILLINOIS

GRADUATE COLLEGE

DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

Teaching and graduate research are
not, in general, reported herein.

May 1, 1954 - May 31, 1954

I. MATHEMATICAL RESEARCH AND PROGRAMMING.

(This work is supported in part by ONR Task 30.)

Solution of Algebraic Equations. Further tests have been made of the program for solving algebraic equations, a polynomial having 100 randomly chosen complex roots being treated. The coefficients of this polynomial did not define the roots to sufficient accuracy for determination of all the roots. This is evidence of a conditioning effect similar to that occurring in the solution of sets of simultaneous linear algebraic equations. In other tests some of the roots required an excessive number of iterations for their determination. This is being investigated. The program is being written up for the library.

Boolean Algebra. Some preliminary studies have been made of the system of Boolean functions of six variables preparatory to its investigation with the computer. Several conjectures have been made concerning the net of order $n/4$. They are: a) All members of the net of order $n/4$ have coordinates in the system formed by the net of order $n/2$ which are equal to the same power of 2 in magnitude or which are equal to zero. b) The number of such points whose coordinates are 2^{p-2} or zero in magnitude is $\frac{2^p\,(2^p-1)\,(2^p-2)}{3!}$ and the number whose coordinates are 2^{p-3} or zero in magnitude is $2^p\,\frac{(2^p-1)\,(2^p-2)\,(2^p-4)\,(2^p-8)}{3!\;5!}$ These two conjectures are based on the results with $p \leq 5$. They may be checked in the case $p=6$ in the future. Such questions as these are of importance in the theory of error detection.

Drum Playback Routines. Two playback routines are now being used in testing the magnetic drum. With the present word arrangement (consecutive words approximately 360 degrees apart on the track) the first routine requires 18 seconds and the second 23 seconds to play back a ten-word block one hundred times. The longer time here is

caused by reading more words; the second program always uses a fixed number of digits for an address in an order while the first suppresses any non-significant zeros there may be. Because the second program is faster than the first (by a factor of about three) at performing the calculations required for playback it will have an advantage when consecutive words are stored 45 degrees or 180 degrees apart.

Matrix Manipulations. Library program M3, the automatic eigenvalue-eigenvector program, has been made into a closed routine because of needs in certain statistical applications where eigenvalues are needed for an iterative procedure. In testing for significance in multivariate analysis the ratio of two determinants is found by dividing the product of one set of eigenvalues by another.

Further investigation is being made of better matrix inversion techniques.

II. LIBRARY ROUTINES.

During May the following program was added to the Illiac library.

M4 (136)	Closed eigenvalue-eigenvector program. 163 words.

III. MACHINE USE.

The following list gives problem specifications for new problems which were tried in May. It does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 313.

NUMBER	PROBLEM SPECIFICATION	AFFILIATION
313	Antenna input impedance	Elect. Eng.
314	Matrix multiplication	Psychology
315	Integration of products	Physics
316	Series peaking display	Elect. Eng.
317	Tool-chip temperature distribution	Mech. Eng.
318	Meson target geometry efficiency	Physics
319	Comparison of factor and scale analysis	Psychology

NUMBER	PROBLEM SPECIFICATION	AFFILIATION
320	Mechanical problems analysis	Psychology
321	Factor analysis (Thesis)	Psychology
322	Single degree of freedom system with damping	Struct. Eng.
323	Factor analysis	Psychology
324	Correlation matrix	Psychology
325	Tobacco demand study	Agr. Econ.
326	Evaluation of residues	Computer
327	Two-mass shear beam	Struct. Eng.
328	Unit cost comparison	Bus. Econ. Res.
329	CO_2 in soil diffusion	Agronomy
330	Factor analysis	Psychology

Table I shows the distribution of machine time for the month of May.

TABLE I

	H:M
Eng. (8-12)	53:46
Eng. (All other times)	26:58
RAR	10:11
Leapfrog	29:02
Wasted	:32

USE OF COMPUTER BY GROUPS

Demonstrations	3:54
Computer Group	22:53
Classes	6:12
Cosmotron	32:47
Physics	32:49
CSL	48:48
Struct. Res.	24:16
Struct. Res. (AF 24994)	15:39
Psychology	10:55
Psychology (AF 25726A)	9:34
Elect. Engineering	8:20
Chemistry	1:17
Agriculture	7:30
Public Health (3M9020C3)	9:07
Indiana University	12:57
Miscellaneous	4:51
	372:18

IV. ERROR FREQUENCY AND ANALYSIS.

The machine is normally used for "engineering" and maintenance between 8:00 A.M. and 12:00 N, and for a check of its performance between 5:00 P.M. and 5:30 P.M. of each weekday. Since the periods between 8:00 in the morning and noon, together with certain other irregular periods like Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more instructive from an error analysis standpoint to look at the periods between noon and midnight of each weekday in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind a summary table has been prepared using the period between noon and midnight of each weekday. This table lists the running time when the machine was operating, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 5:00-5:30 P.M. period (when the machine is checked) if no errors are found, the time is given to the "running column." Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that any interruption of machine time that was not planned for is considered a failure in this table. In rare cases where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This overall system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" at any instant of time and the probability of a failure during any given interval of running time.

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	POSSIBLE OPERATOR ERROR	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
5/3/54	11:33	:27	2	Yes	(1) Two different results from same tapes.	:00	:50	1
				No	(2) Dirt in light bulb prevented reading of one hole.			
5/4/54	11:16	:44	2	No	(1) Reader C failed to stop properly.	:00	:18	1
				No	(2) Reader B failed to stop properly.			
5/5/54	11:11	:49	1	No	(1) Error in 2^{-12}, probably in memory.	:00	:24	1
5/6/54	8:56	2:39	2	No	(1) Morning engineering runover to fix 2^{-26}.	:25	:32	0
				No	(2) Armature spring on reader B broke.			
5/7/54	10:15	1:45	5	Yes	(1) Two different results from same tapes.	:00	:29	1
				Yes	(2) Two different results from same tapes.			
				No	(3) Memory failure 2^{-31}(shorted amp. tube)			
				Yes	(4) Two different results from same tapes.			
				No	(5) Fuse blew +150V circuit no. 5.			
5/10/54	11:59	:01	1	No	(1) Reader brake on.	:00	:20	0
5/11/54	11:62	:58	1	No	(1) Reader B read a nine twice.	:00		1
5/12/54	11:56	:04	4	Yes	(1) Two different results from same tapes.	:00	:19	0
				Yes	(2) Two different results from same tapes.			
				Yes	(3) Two different results from same tapes.			
				Yes	(4) Two different results from same tapes.			
5/13/54	11:54	:06	1	No	(1) Morning Engineering run-over.	:00	:25	0

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	POSSIBLE OPERATOR ERROR	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
5/14/54	11:58	:02	2	Yes	(1) Two different results from same tapes.	:00	:20	0
				Yes	(2) Two different results from same tapes.			
5/17/54	11:44	:01	1	Yes	(1) Two different results from same tapes.	:15	:20	0
5/18/54	11:51	:01	1	No	(1) Scope output not possible because of bad filament connection.	:08	:27	0
5/19/54	11:58	:01	1	Yes	(1) Two different results from same tapes.	:01	:29	0
5/20/54	9:32	2:28	1	No	(1) Reader E and reader C braked at times when they should not have done so.	:00	:20	0
5/21/54	11:28	:32	1	No	(1) Morning engineering run-over.	:00	:48	0
5/22/54	11:57	:01	1	Yes	(1) Two different results from same tapes.	:02	:21	0
5/25/54	11:04	:56	2	No No	(1) Fuse blew +300 circuit number 3. (2) Reader E not braking properly.	:00	:26	0
5/26/54	11:56	:04	1	Yes	(1) Unknown but possibly a 0 ⟶ 1 in 2^{-2}.	:00	:24	0
5/27/54	12:00	:00	0			:00	1:05	0
5/28/54	11:37	:19	0			:04	:16	0
TOTALS	227:07	11:58	29			:55	9:06	5

V. COMMENTS ON THE MACHINE.

Reader errors. For some time we have had a very large number of errors associated with the reading or punching of tapes. Indeed, a study of the past several months shows that most of the machine errors are associated with the processes of reading tapes into the machine. Since the process of reading a tape is also associated with the operator of the machine, it is possible that some of the errors, at least, may be associated with the handling of the tapes while they are being inserted into the tape reader. It is also possible that some of the errors may be associated with incorrect operation of the operator's switches. For this reason, the error analysis sheets have an added column which shows those cases in which it is possible that the operator may be responsible for errors. It is obvious that the error may not have been due to the operator.

During the month, it was found that if the switch on the punch output for feeding out extra tape was used while a tape was being read into the machine, errors sometimes occurred. The process of changing the switch from the "off" position to the "on" position resulted in very large transients in the dc power lines in the input-output rack and these transients sometimes caused errors in the reading circuits. This was repaired on May 27 and the errors which are associated with this particular kind of difficulty should have been eliminated. It should be noted that it has been a common practice for all individuals operating the machine to momentarily use this switch on the punch to obtain an extra length of tape while a program tape is being read into the machine.

Transients caused by using the ac on-off switch on the punch could also cause errors. Since this switch is not used during normal operation of the computer, this difficulty probably is not responsible for many errors. The difficulty has been eliminated.

Memory. No errors were associated with the cathode ray tube during the month except those which were associated with the small tubes in the regeneration chassis.

VI. RESEARCH ON COMPUTER COMPONENTS. (This work is supported in part by ONR Task 24.)

Magnetic Drum Memory. Extensive tests have been carried out during the month using the four tracks on the magnetic drum which are currently available for use with the Illiac. It was found that one of the errors which had occurred previously was due to a switching transient which resulted, in some cases, in an error immediately following the change of the address for a drum order. It was possible to reduce this transient by putting a "bumper" on the excursion of the switched voltage coming from the preamplifiers. By this means, this source of error has been eliminated.

Because of the extensive periods over which these drum tests have been carried out, some of the tubes in the circuits have developed shorts and it was necessary to spend some time eliminating the faulty tubes. Although the errors from this source have been very much reduced, there are still some cases when unexplained errors have occurred. One source of error which has been extensively investigated is the coating on the drum surface. Because the coating on the present drum is relatively thin, it is apparently not uniform so that even if the surface is uniformly magnetized to saturation during a recording process, noise voltages are generated on playback, the amplitudes of which amount to 10% of an ordinary signal. Because this difficulty can be eliminated by a thicker coating on the drum and because the amplitude of the signal itself will be increased, it is now anticipated that the drum will be recoated with a thicker layer of the magnetic material.

A hang-up circuit has been added which will prevent the execution of a drum order if the word counter is out of synchronization.

Recently it has been possible to read or write from the drum for a number of one-hour periods without error when tranfers take place as often as every eighth word. However, one recent run was terminated by an unexplained error.

At the present time it appears that the drum circuits are operating satisfactorily except for some occasional synchronization errors which have occurred. However it still seems very important to recoat the drum with a thicker layer of material in order to improve the signal to noise ratio.

VII. REPORTS AND SEMINARS.

Seminars.

"Recent Progress in the Coiling Polymer Chain Problem," by Professor F. T. Wall, May 5, 1954.

"The Convergence Rate of an Iterative Process," by R. T. Gregory, May 12, 1954.

"Solutions to the Helium Wave Equation," by Professor J. H. Bartlett, May 19, 1954.

"High Speed Information Searching Using Electronic Digital Computer Techniques," by John L. Muerle, May 26, 1954.

Papers.

"Interpretive Routines in the Illiac Library," presented at ONR Symposium on Automatic Programming, by D. E. Muller, Washington, D.C., May 14, 1954.

"A High Speed Fixed Magnetic Memory," by J. M. Wier, submitted for publication in Transactions of Professional Group on Electronic Computers of the IRE, May 28, 1954.

VIII. CONSTRUCTION.

The shop has carried out the following design or construction work:

1. A number of laboratory circuits have been built.
2. A new cassette which will hold up to 100 ft. of film and which is motor-driven has been designed for the cathode ray tube output to receive exposed film.
3. The third and fourth readers constructed in the shop, called readers "D" and "E" have been finished. These tape readers have a larger drive motor to prevent stalling of the tape under some conditions and certain other improvements have been made.

4. A circuit has been designed and built to bench test the readers under conditions similar to those used on the Illiac.
5. The machining of selector bars for the Teletype keyboards of the Model 19 sets has continued.
6. Work has started on making about 170 sub-chassis units which will go into the magnetic core memory for the Control Systems Laboratory.
7. Two dc supply transient indicators were built and installed.
8. Tests were made on coating the small magnetic drum so that a successful job can be anticipated for the main drum.

IX. PERSONNEL.

The personnel associated with the group and hence the contributors to this report are:

Bateman, Wm. E.
Brown, Mrs. Caroline (3/4 time)
Carter, Clifford E.
Clements, Virgil F.
Courter, Mrs. Helen
Ehrlich, George
Fishel, Jerome (1/2 time)
Gill, Stanley
Golub, Gene (1/2 time)
Gregory, R. T. (1/4 time)
Hill, Robert (Student Assistant)
Huffman, W. L.
Kerkering, T. E.
Kudlich, R. A. (RCA Fellow)
Lopeman, H. E.
Lobaugh, Wm. R. (Started May 5, 1/2 time)
Meagher, R. E.
Metze, G. A. (Will start June 16)
Michael, G. W.
Miller, R. E. (1/2 time)
Muerle, John (1/2 time)
Muroga, Saburo (Will start June 16)
Muller, D. E.
Nash, J. P.
Newmark, N. M. (Chairman, Exec. Comm.)
Ogata, Albert I. (Student Assistant)

Polivka, R. P. (1/2 time)
Robertson, J. E.
Russell, Miss Ramona J.
Seshu, Mrs. Lily (1/2 time)
Shapin, Theodore, Jr. (CSL)
Stephens, Allen
Taub, A. H. (On Sabbatical Leave)
Wier, J. M.
Yu, Hwa-Hien (1/2 time)

The work of the group is under the administration of an Executive Committee with the following members: N. M. Newmark, Chairman, Stanley Gill, D. E. Muller, J. P. Nash, J. E. Robertson, A. H. Taub, and R. E. Meagher.

R. E. Meagher.

R. E. Meagher

REM/hc

TO: Executive Committee, Digital Computer Laboratory

FROM: R. E. Meagher

DATE: July 20, 1954

I am enclosing a technical progress report for the month of June, 1954.

A financial statement prepared by Mr. George Michael is attached.

R. E. Meagher

R. E. Meagher

DIGITAL COMPUTER

FINANCIAL REPORT
June 30, 1954

	DIGITAL COMPUTER	DIGITAL COMPUTER INDIRECT COST	GRAD. IND. COST COMPUTER	COMPUTER SERVICE	U.S. NAVY TASK 24	U.S. NAVY TASK 30	TOTAL
FREE BALANCE	O.D. - .08	3232.19	1,185.64	18,214.00	48,848.96[1]	35,101.45[2]	106,582.16
EQUIPMENT	691.40			16,181.95			16,873.35
MATERIALS	9,177.35			26,745.41	11,512.15	78.45	47,513.36
SALARIES/WAGES	71,158.98		5,500.00	34,685.87	30,004.58	22,477.93	163,827.36
OVERHEAD					12,014.17	8,663.31	20,677.48
WORKMANS COMP.					508.59	435.70	944.29
RETIREMENT			428.50	163.20	925.20		1,516.90
TRAVEL	298.24			220.40	850.35	659.71	2,028.70
TELE./TELEG.	728.98			622.89		69.05	1,420.92
BUILDING							
	82,054.95		5,928.50	78,619.72	55,815.04	32,384.15	254,802.36

Funds Expended - Previous Allowances........	570,055.36
Total Expenditures, 2/1/49 to date..........	824,857.72

[1] Through June 30, 1956

[2] Through June 15, 1956

UNIVERSITY OF ILLINOIS

GRADUATE COLLEGE

DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

Teaching and graduate research are not, in general, reported herein.

June 1, 1954 - June 30, 1954

I. MATHEMATICAL RESEARCH AND PROGRAMMING. (This work is supported in part by ONR Task 30.)

Boolean Algebra

A theory has been developed for finding an upper bound for the number of error correcting codes satisfying a minimum distance criterion. This upper bound is much lower than the upper bound previously described by Fano and which was thought to be obtainable by suitable coding, a belief based on a theorem of Shannon's which describes the capacity of a noisy channel. The new upper bound has been achieved by actual codes formed from polynomial nets (see Internal Report 46.)

Programs have been prepared for studying error correcting codes having 2^6 bits. These programs are now being machine tested.

Magnetic Drum Recording Routine

A recording routine for testing one of the drum playback routines mentioned in last month's report is now being tested.

Cathode Ray Tube Output Program

A program for converting punch output orders to cathode ray tube display orders has been completed and is undergoing various tests.

Matrix Manipulations

The present library programs for finding eigenvalues and eigenvectors of symmetric matrices find all of the roots and vectors. A new program is now being written which will find the roots and vectors in order of size of the roots. It will permit handling larger matrices.

Floating Point Auxiliary

An arctangent auxiliary for Library Program A1 is being written.

II. LIBRARY ROUTINES.

During June the following program was added to the Illiac library. It was written by R. A. Rubenstein of the Physics Department.

K3 (137) Least Squares. Complete Program.

The program produces the values required for evaluating the coefficients of the least squares polynomial in a form which can be used with the simultaneous equations library programs L2 or L3.

III. MACHINE USE.

The following list gives problem specifications for new problems which were tried in June. It does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 331.

NUMBER	PROBLEM SPECIFICATION	AFFILIATION
331	Second order differential equation	Structural Research
332	Calculation of phi coefficients	Psychology
333	Eleastic beam-column	Structural Research
334	Simultaneous trigonometric equations	Physics
335	Surface conductivity in a semiconductor	Physics
336	Cost functions of retail store (Thesis)	Marketing
337	Pupil ratings of teachers	Bur. Ed. Research
338	Cathode ray tube display	Computer
339	Analysis of variance	Bur. Ed. Research
340	Analysis of classroom practice	Bur. Ed. Research
341	Semantic relations study (Thesis)	Psychology
342	Largest eigenvalues of a matrix	Computer
343	Elastic π^0 production in He^4.	Physics
344	Three-mass shear beam	Structural Research
345	Potential in electro-chemical transistor model	Physics
346	Antenna impedances	Electrical Engineering
347	Factor analysis (Thesis)	Psychology
348	Rorschach correlational analysis	Psychology
349	Measurement of proficiency	Chanute AF Base

Table I shows distribution of machine time for the month of June.

TABLE I

Eng. (8:00-12:00)	37:48
Eng. (Other Times)	26:54
R.A.R.	9:57
Leapfrog	47:31
Wasted	:48

Use of Computer by Groups

Computer Group	12:32
Classes	2:51
Cosmotron	94:18
Physics	81:59
C.S.L.	47:45
Struct. Res.	9:11
Struct. Res. (AF 24994)	8:27
Psychology	9:53
Psychology (25726A)	12:12
Elec. Eng.	1:19
Chemistry	1:04
Agriculture	11:16
Indiana University	9:05
Miscellaneous	5:15
Demonstration	2:47
	432:52

IV. ERROR FREQUENCY AND ANALYSIS.

The machine is normally used for "engineering" and maintenance between 8:00 A.M. and 12:00 N, and for a check of its performance between 5:00 P.M. and 5:30 P.M. of each weekday. Since the periods between 8:00 in the morning and noon, together with certain irregular periods like Saturdays and Sundays, are devoted to a heterogeneous group of functions,

it is more instructive from an error analysis standpoint to look at the periods between noon and 4:00 A.M. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind a summary table has been prepared using the period between noon and 4:00 A.M. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 5:00-5:30 P.M. period (when the machine is checked) if no errors are found, the time is given to the "running column." Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that any interruption of machine time that was not planned for is considered a failure in this table. In rare cases where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This overall system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" at any instant of time and the probability of a failure during any given interval of running time.

It should be noted that during the month of June the error analysis covers a sixteen-hour period for each day instead of the former twelve-hour period. This corresponds to an extension in running time for the machine of four hours per day.

V. COMMENTS ON THE MACHINE.

There were seven error-free days during the month and a total of thirty-three errors, indicating an error rate of about one per ten hours.

The keyboard modifications for all teletype units have been completed and agree with the code sheet shown in the manual on programming.

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
6/1/54	15:50	:10	1	YG-GG Switch had broken wire.	:00	:26	0
6/2/54	15:47	:11	1	Pin in brake of reader came out.	:02	:46	0
6/3/54	16:00	:00	0		:00	:20	0
6/4/54	14:23	1:33	7	(1) Two different results from same tapes. (2) Two different results from same tapes. (3) Tape moved sideways in reader D. (4) Two different results from same tapes. (5) Brake stuck on reader E, (6) Two different results from same tapes. (7) Two different results from same tapes.	:04	:00	0
6/7/54	15:53	:00	0		:07	:41	
6/8/54	12:14	3:46	3	(1) Two different results from same tapes. (2) Bad tube 2^{-17} R II Black Gate. (3) Bad tube 2^{-17} R II Black Gate.	:00	:50	0
6/9/54	10:27	5:33	2	(1) Probably reader read space as character. (2) Leapfrog division failure.	:00	:06	1
6/10/54	16:00	:00	0		:00	:48	0
6/11/54	15:13	:44	1	(1) Leapfrog 0-1 2^{-37}, chassis changed.	:03	2:10	1
6/14/54	15:59	:00	0		:01	2:30	0
6/15/54	12:45	3:15	1	(1) Flipflop R^1-2^{-16} short G_2 to cathode. (a) Unsoldered connection between R_1 and adder 2^{-39}. (b) Wire crossed from memory to R^3 in about 2^{-36} pos. (c)	:00	1:29	0
6/16/54	15:58	:02	2	(1) Two different results from same tapes. (2) Unknown.	:00	1:55	0
6/17/54	15:57	:02	2	(1) Punch No.2 not advancing. (2) N not recognized during reading.	:01	1:42	0

TABLE II

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
6/18/54	16:00	:00	0		:00	2:00	0
6/21/54	15:40	:20	5	(1) Two different results from same tapes. (2) Reader error with reader D. (3) Hang-up on D.O.I. (4) Tape ran on through the reader. (5) Leapfrog error, address altered.	:00	2:46	1
6/22/54	13:39	2:21	2	(1) Punch No. 2 punched extra characters. (2) Leapfrog division error.	:00	:53	1
6/23/54	15:53	:07	3	(1) Run-over from morning Eng. (2) Punch No. 2 punched extra characters. (3) Punch No. 2 punched extra characters due to grid-cathode short.	:00	1:13	0
6/24/54	12:52	3:08	1	(1) Leapfrog but otherwise unknown.	:00	1:44	1
6/25/54	15:19	:41	1	(1) $0 \rightarrow 1$ 2^{-37} location 0.	:00	:59	1
6/28/54	13:42	2:18	1	(1) Run-over from morning Eng.	:00	:49	1
6/29/54	16:00	:00	0		:00	1:12	0
6/30/54	15:59	:00	0		:01	:50	0
Totals	327:30	24:11	33		:19	26:09	9

VI. RESEARCH ON COMPUTER COMPONENTS. (This work is supported in part by ONR Task 24.)

Magnetic Drum Memory.

During the month the magnetic drum has been recoated to provide a more uniform iron oxide coating of about 0.0015 in. This new coating has increased the signal size provided by the heads by a factor of almost two. The signal to noise ratio of the signal has been improved by about the same factor. As a result of the recoating it was necessary to record again the four control tracks which provide the indeces for various locations on the drum.

After the recoating and the recording of the control tracks, four information tracks were placed in operation. Three of these tracks worked almost immediately without difficulty when the signal amplitudes as they came from the heads were adjusted to the proper levels. The fourth track has not operated satisfactorily because of the head.

Before the drum was recoated the allowed tolerances in gain on the pre-amplifiers were of the order of ± 10% during an ordinary test run with the drum test code. After the recoating of the drum this tolerance was broadened to about ± 30% showing a considerable improvement in the safety factor.

Direct-Coupled Transistor Circuits.

A junction transistor "NOT" circuit using a clamped Zener diode has been built for test purposes. Various voltage levels which were designed to work with the circuit were used as inputs to the "NOT" circuit. Outputs were observed and were found to be well within the calculated design range.

The design of this circuit is based on the assumption that the breakdown voltage of the Zener diode is 3/4 of the collector supply voltage and a 10% tolerance is allowed on the breakdown voltage of the diode.

The circuit has also been tested ac-wise. The delay time was found in the order of one microsecond having no appreciable delay introduced by the Zener diode. The circuit also works indiscriminately before or after a gated flip-flop circuit using point-contact transistors.

A non-saturated flip-flop circuit has also been built. Combinations from 13 of the 1698 point-contact transistors were tested in the flip-flop circuit. Most of the transistors work successfully in the circuit. The reasons why some transistors would not work satisfactorily were determined.

Presentation of Alphanumerical Data on the Cathode Ray Tube Unit.

At the present time characters can be displayed on the cathode ray tube unit at the rate of about 45 per second using an interpretive routine stored on the Williams memory to display a character on 5x7 array of spots. If a suitable matrix unit were constructed to carry out this interpretive process the presentation speed could be increased to about 1000 characters per second. This would make it possible to make the output speed of the machine quite comparable to the computational speed of the machine.

VIII. CONSTRUCTION.

The work in the shop has consisted mainly of construction of components for the magnetic core memory for the Control Systems Laboratory. Work has been carried out on the frame of the unit as well as on the individual chassis. A list of the chassis which are necessary together with the status of each is given below as Table III.

TABLE III.

Chassis Dwg. No.	Assembled	Wired
580	Yes	Yes
582	Yes	Yes
579	Yes	Yes
581	Yes	Yes
576	Yes	Partially
571	Yes	No
573	Yes	No
565	Yes	No
572	Not started	
552	Not started	

TABLE III(Cont.)

Chassis Dwg. No.	Assembled	Wired
567	Not started	
570	No	No
578	Not started	

The shop made the preparations and coated the magnetic drum unit. A number of miscellaneous components were built or worked on by the shop which included the following: repairs on readers, film supply indicator for the cathode ray tube unit, construction of two hand punches for correcting errors in teletype tapes, and construction of selector bars for teletype printers.

VIII. PERSONNEL.

The personnel associated with the group and hence the contributors to this report are:

Bateman, Wm. E., Jr. Electronics Technician
Brown, Mrs. Caroline, Computer Teletype Operator (3/4 time)
Carter, Clifford E., Electronics Engineer for Illiac
Clements, Virgil F., Jr. Laboratory Mechanic
Courter, Mrs. Helen, Clerk-Stenographer III
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Muroga, Saburo, Research Associate (Started June 16)
Muller, D. E., Res. Asst. Prof. of Applied Math.
Nash, J. P., Res. Prof. of Applied Math.
Newmark, N. M. (Chairman, Exec. Comm.)
Ogata, Albert I., Student Assistant

Polivka, R. P., Research Assistant
Robertson, J. E., Res. Asst. Prof. of Elec. Eng.
Russell, Miss Ramona J., Computer Operator for Illiac
Seshu, Mrs. Lily, 3/4 time Research Assistant
Shapin, Theodore, Jr., (CSL) Research Associate
Spandau, Kenneth L., Jr. Electronics Technician (Started June 1)
Stephens, Allen, Asst. Laboratory Mechanic
Taub, A. H., Research Prof. of Applied Math. (On Sabbatical Leave)
Wier, J. M., Research Associate
Yu, Hwa-Nien, Research Assistant

The work of the group is under the administration of an Executive Committee with the following members: N. M. Newmark, Chairman, D. E. Muller, Stanley Gill, J. P. Nash, J. E. Robertson, A. H. Taub, and R. E. Meagher.

R. E. Meagher.
R. E. Meagher

REM/hc

UNIVERSITY OF ILLINOIS
GRADUATE COLLEGE
DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

Teaching and graduate research are not, in general, reported herein.

July 1, 1954 - July 31, 1954

I. MATHEMATICAL RESEARCH AND PROGRAMMING.

(This work is supported in part by ONR Task 30.)

Boolean Algebra

A program for locating 6-variable Boolean functions lying outside the net of order 16 but satisfying the distance condition $L(h,r^i) \geq 16$ for all r^i in the net has been run on the Illiac. A number of such functions h have been found, and in two cases a pair h_1, h_2 were found such that the distance condition was simultaneously satisfied, giving $L(h_1 + h_2, r^i) \geq 16$. Results of a search for functions h containing only two terms of fourth degree showed that none exist. A general transformation has been developed which makes it possible to produce new functions h from known ones.

An analytical proof has been given of the distance condition which is satisfied by all of the functions h which were found. This proof permits generalization to a large number of cases in systems with more variables. It was also shown that a function satisfying the distance condition in the 6-variable net of order 16 has all six variables and none as a factor, and that if it has only three terms it is isomorphic with

$$h = x^5x^4x^3 + x^6x^4x^2 + x^6x^5x^1$$

An investigation with the Illiac of the characteristic functions for the 6-variable net of order 16 verified the conjectures made in the report of June 22nd.

A proof has been given that the probability is P that an error-correcting code satisfying Shannon's maximum density criterion may be obtained by means of a random selection process. The value of P approaches 1 as the length of the code approaches infinity.

Matrix Manipulations

Library routine M1 for matrix multiplication is being rewritten as two separate routines, one open and one closed. Work is being done on finding eigenvalues and eigenvectors of non-symmetric matrices.

Magnetic Drum

The drum testing routine has been altered to permit recording on 1, 2, 4, or 8 tracks and it is possible to record any word continually at any location.

Some time comparisons have been made with the two existing playback routines, a set of ten words having been played back one hundred times with each routine. Results obtained were as follows:

Routine	Words Stored Consecutively	Words Spaced 8 Locations Apart	Words Spaced 16 Locations Apart
M	19 sec	21 sec	25 sec
P	23 sec	24 sec	13 sec

The time between successive calls to the playback order is the time required to change the drum word into order pairs for normal Illiac use. In Routine M this time varies from 7 milliseconds to 8.8 milliseconds; in Routine P it varies from 3.3 milliseconds to 3.8 milliseconds. The time actually available for maximum playback efficiency depends upon how words are stored on the drum. The time is 17 milliseconds, 6.5 milliseconds or 2.2 milliseconds for words stored consecutively, 16 locations apart, or 8 locations apart, respectively. Ideally the time required by the routine should be less than 2.2 milliseconds. It seems unlikely that it will be achieved.

II. LIBRARY ROUTINES.

During July the following two programs were added to the Illiac Library.

M5 (139)	Solution of the Determinantal Equation $|A-\lambda B| = 0$. Complete Program. The program is for symmetric matrices, and B must be positive definite. The number of variables is restricted to 17. Eigenvalues and normalized eigenvectors are computed.
T4 (140)	Arctangent Subroutine. 25 Words. This program is a faster and shorter version of T2.

III. MACHINE USE.

The following list gives problem specifications for new problems which were tried in July. It does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 350.

NUMBER	PROBLEM SPECIFICATION	AFFILIATION
350	Anxiety factor analysis	Psychology
351	Error-free coding	Computer
352	Damage pressure levels	Structural Research
353	Hartree wave functions for copper	Physics
354	Damage pressure levels	Structural Research
355	Thurstone matrix study	Psychology
356	Estimation of communalities	Psychology
357	Eigenvalue differential equations	Physics
358	Characteristic 6-variable logical function	Computer
359	DC flipflop design	CSL
360	Table of $\phi_1(\gamma)$ and $\phi_2(\gamma)$	Physics
361	Accuracy of approximate damage pressure level	Structural Research
362	Slab investigation	Structural Research
363	Multiple Correlation	Sociology
364	Mental health factor analysis	Inst. Comm. Research
365	Hartree wave functions	Physics
366	Simultaneous equations	Agricultural Economics
367	Fourth order central force	Physics
368	Single degree of freedom system with impulse loading	Structural Research

Table I shows distribution of machine time for the month of July.

TABLE I

Eng. (8:00-12:00)	59:04
Eng. (other times)	31:29
RAR	6:53
Leapfrog	62:32
Wasted	:38

Use by Departments

Computer Group	55:04
Cosmotron	73:27
Physics	62:36
Control Systems Lab.	46:48
Structural Research	8:13
St. Res. (AF 24994)	33:00
St. Res. (NOBS 62250)	12:32
Psychology	16:50
Psychology (AF 25726A)	22:51
Elec. Eng.	3:53
Chemistry	18:02
Agriculture	7:59
Indiana University	6:39
Chanute Air Base	2:27
Demonstrations	1:08
Miscellaneous	9:16
Total	541:21

IV. ERROR FREQUENCY AND ANALYSIS.

The machine is normally used for "engineering" and maintenance between 8:00 A.M. and 12:00 N, and for a check of its performance between 5:00 P.M. and 5:30 P.M. of each weekday. Since the periods between 8:00 in the morning and noon, together with certain irregular periods like Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more instructive from an error analysis standpoint to look at the periods between noon and 8:00 A.M. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind a summary table has been prepared using the period between noon and 8:00 A.M. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 5:00-5:30 P.M. period (when the machine is checked) if no errors are found, the time is given

to the "running column." Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that any interruption of machine time that was not planned for is considered a failure in this table. In rare cases where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This overall system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" at any instant of time and the probability of a failure during any given interval of running time.

It should be noted that during the month of July the error analysis covers a twenty-hour period for each day instead of the former sixteen-hour period. This corresponds to an extension in running time for the machine of four hours per day, and the machine is now turned on for the entire period between 8:00 A.M. Monday and 8:00 A.M. Saturday.

V. COMMENTS ON THE MACHINE.

There were three error-free days during the month and a total of forty-six errors, indicating an error rate of about one error for each ten hours of operation.

A relatively large number of memory errors occurred, caused mostly because of tube failures in the address generator and in chassis associated with various memory positions.

VI. RESEARCH ON COMPUTER COMPONENTS. (This work is supported in part by ONR Task 24.)

Direct Coupled Transistor Circuits

A transistor shift register was built and tested. Since only a limited number of junction transistors were on hand, the register has only two binary digits, and the gating pulses are provided from a vacuum tube circuit.

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
7/1/54	19:58	:02	2	(1) Read an extra "0" (2) Unknown. Possible short in 2^{-31} R_1 flip-flop.	:00	1:36	0
7/2/54	19:00	:58	2	(1) Run over of Eng. (2) Unknown.	:02	1:13	0
7/5/54				Computer Laboratory closed for holiday			
7/6/54	16:48	3:10	4	(1) Chassis "C" V50 (Multiplication correction C.F.) K-F Short 6BQ7. (2) -300v Power Supply off. (3) -300v Power Supply off. (4) Reader light went out.	:02	1:35	1
7/7/54	20:00	:00	0		:00	2:30	0
7/8/54	18:51	1:09	2	(1) Flip-flop 2^{-11} R_1 was being held to "0." (2) Reader light burned out.	:00	2:44	0
7/9/54	19:01	:59	3	(1) Trouble in transfer to D.O.I. (2) Leapfrog failed. Probably caused by drum. (3) Different results from same data tapes. (Reason unknown.)	:00	2:26	1
7/12/54	19:53	:07	2	(1) Reader error. "D" changed to "C." D Voltage set wrong. (2) Reader error. "C" changed to "E."	:00	2:58	0
7/13/54	18:52	4:01	3	(1) Dirt in reader. (2) Short G_2-K in V27-RI2^{-21} (3) -300v Power Supply off.	:01	1:43	1
7/14/54	19:35	:25	3	(1) Chad box full. (2) Unknown. (3) Bare wire on punch cable.	:00	3:07	0
7/15/54	19:30	:30	1	(1) Input-output error. Leapfrog.	:00	2:13	1
7/16/54	18:48	1:12	4	(1) -300v power supply off. (2) Memory chassis 2^{-39} failed. (3) Reader error. Reader "D."	:00	2:47	0

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
7/16/54				(4) Reader error. Reader "D."			
7/19/54	17:00	2:52	2	(1) 2^{-2} R_3 replaced (G_2 P_2 short) (2) Unknown.	:08	1:51	0
7/20/54	18:46	1:14	3	(1) Leapfrog 2^{-2} $0 \to 1$ failure. Memory Pos. 18. (2) Two different results from same tapes. (3) Tube with broken pin in RII, one tube G_2-K short, (V_{22}-V_{34})RII 2^{-10}-2^{-19}	:00	:52	1
7/21/54	19:53	:04	4	(1) Two different results from same tapes. (2) Indications of $0 \to 1$ failures 2^{-37}. (3) Memory pos. 37. (4) Memory $0 \to 1$ 2^{-37}.	:03	:59	0
7/22/54	19:56	:01	1	(1) Memory pos. 37	:03	1:39	0
7/23/54	15:23	4:35	4	(1) Reader error. Reader "D." (2) Failure to shift 2^{-16} R_1 because of a shorted tube. (3) $0 \to 1$ in 2^{-37}. (4) 2000v power supply failure.	:02	1:08	1
7/26/54	20:00	:00	0		:00	1:06	0
7/27/54	19:11	:49	3	(1) Unknown. (2) +300v power supply failure. (3) Unknown.	:00	:45	0
7/28/54	19:58	:01	1	(1) Unknown	:01	:31	0
7/29/54	19:58	:00	0		:02	:43	0
7/30/54	19:55	:05	2	(1) Reader "D" stalling. Reader error. (2) Hung up on an 82 order. (Scope output order)	:00	:45	0
Total	397:25	22:11	46		:24	35:11	6

The register has been operated without error for periods up to forty minutes. Considerable difficulty has been experienced with the power supplies being used and with heating of the transistors.

It is planned that a fairly extensive amount of logical circuitry will be built up when more transistors are obtained. The logical design of this circuitry is now under way.

Magnetic Core Memory

The core tester for the small memory being built for the Control Systems Laboratory has been completed and the testing of cores has been started.

Magnetic Drum Memory

During the month the capacity of the experimental drum unit was increased from four to eight information tracks by installing four additional preamplifiers and a two-binary-digit matrix for preamplifier selection. The drum test code was modified for testing the eight track unit. The gains of the preamplifiers now in service were checked and found to be within the prescribed tolerance limits.

The head assemblies which were removed for recoating the drum were replaced and the head to drum spacing was reset for each of the 214 heads. The spacing was initially set to 0.002 inch, and was later reset to 0.0015 inch.

The control track amplifiers were set to the prescribed gain and input level settings. Noise pickup at the inputs of these amplifiers was eliminated by shielding the input bleeder resistors.

The drum test code ran without error for ninety minutes when recording and reading occurred on all eight tracks. When recording and reading from one track only, however, intermittent reading errors occurred. Investigation of these errors was continuing at the end of the month.

The control track and test recording circuits were modified to find the overall frequency response for recording and reading using the drum with the new coating. Data were taken for a head for which past data were available. Readings were made from 3KC to 160KC for head spacings of 0.0010, 0.0015, 0.0020, and 0.0030 inch. The frequency response corresponds very closely to that found in the past, except that the signal amplitude has increased approximately 15% at 40KC.

VII. CONSTRUCTION.

Shop work has consisted largely of design and construction of the chassis and frame for the magnetic core memory being built for the Control Systems Laboratory. Table III gives the status of chassis for this memory.

Chassis No.	Dwg. No.	Laid Out	Assembled	Wired	Checked
1	580	Yes	Yes	Yes	Ready
1	582	Yes	Yes	Yes	Ready
2-1/2	579	Yes	Yes	Yes	No
1	581	Yes	Yes	Yes	Ready
1	576	Yes	Yes	Yes	Ready
1	571	Yes	Yes	Yes	Ready
1	573	Yes	Yes	Yes	Ready
2-1/3 (3 in 1)	565	Yes	Yes	Yes	No
2/3 "	566	Yes	Yes	Yes	No
1 "	565	Yes	Yes	No	
1	572	Yes	Yes	Yes	Ready
1	552	Partly	No		
1	567	Yes	Yes	Yes	No
1	570	Yes	Yes	No	
1 (3 in 1)	578	Yes	Yes	No	
1 (2 in 1)	578	Yes	Yes	No	
1/2 (2 in 1)	578	Yes	Yes	Partly	

The shop also worked on a number of pieces of equipment as part of the routine maintenance of the Laboratory. Included in these were the following: installation of a new roller in Reader D; repair of hand punches; construction of new tape hand winders; repair of clock-type tape winders.

VIII. PERSONNEL.

The personnel associated with the group and hence the contributors to this report are:

Bateman, Wm. E., Jr., Electronics Technician
Brown, Mrs. Caroline, Computer Teletype Operator (3/4 time)
Carter, Clifford E., Electronics Engineer for Illiac

Clements, Virgil F., Jr. Laboratory Mechanic
Courter, Mrs. Helen, Clerk-Stenographer III
Ehrlich, George, Jr., Engineering Draftsman
Fishel, Jerome, Research Assistant
Golub, Gene, Research Assistant
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Muerle, John L., Research Assistant
Muroga, Saburo, Research Assistant
Muller, D. E., Res. Asst. Prof. of Applied Math.
Nash, J. P., Res. Prof. of Applied Math.
Newmark, N. M., (Chairman, Exec. Comm.)
Ogata, Albert I., Student Assistant
Plahn, Henry W., Student Assistant
Polivka, R. P., Research Assistant
Robertson, J. E., Res. Asst. Prof. of Elec. Eng.
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Seshu, Mrs. Lily, 3/4 time Research Assistant
Spandau, Kenneth L., Jr. Electronics Technician
Stephens, Allen, Asst. Laboratory Mechanic
Taub, A. H., Res. Prof. of Applied Math. (On Sabbatical Leave)
Wier, J. M., Research Associate
Yu, Hwa-Nien, Research Assistant

The work of the group is under the administration of an Executive Committee with the following members: N. M. Newmark, Chairman, D. E. Muller, J. E. Robertson, J. P. Nash, A. H. Taub, and R. E. Meagher.

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UNIVERSITY OF ILLINOIS
GRADUATE COLLEGE
DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

Teaching and graduate research are
not, in general, reported herein.

August 1, 1954 - August 31, 1954

I. MATHEMATICAL RESEARCH AND PROGRAMMING. (This work is supported in part by ONR Task 30.)

Boolean Algebra

Illiac programs have been used for finding additional functions h of the type described in the Technical Progress Report for July. A set of four such functions which satisfy the distance condition previously given has now been found. A search indicates that it is unlikely that more such functions exist.

Studies are being made of error correcting codes in which the number of binary digits is not a power of two. Only partial results have so far been obtained.

A new method depending upon the Gray code system has been devised for finding elements of the augmented net of order d = 8. This method will be used principally with small values of d.

Lossless code systems in which Boolean members lie inside spheres of radius R have been studied. For this purpose a search has been made for N which satisfy

$$\sum_{i=o}^{R} \binom{N}{i} = 2^n$$

where n is a positive integer. Results of the search show that for N between 10 and 40 and for R between 3 and 16 there is no such case except the ones which have been obtained by Golay.

An Illiac program has been devised to find all types of functions h having minimum distance 16 from the net. Thus far only two types have been found, and the program will be modified to speed up the search.

Linear Algebraic Equations

Occasionally, in order to preserve accuracy, a considerable amount of scaling of coefficients in linear equations is required. A routine has been written, using Stiefel's method, for solving sets of linear equations with floating point arithmetic. The program is necessarily slow but is expected to be particularly useful in problems where coefficients over a wide range are generated in the machine.

An investigation is also being made of methods suitable for solving large systems when an auxiliary magnetic drum memory is available.

II. LIBRARY ROUTINES.

During August the following four programs were added to the Illiac Library.

X7 (142)	Sum Check. 11 words. This is an interlude to be placed anywhere in the memory. After being executed it compares the result with a number punched on the input tape, returning control to X1 if there is agreement and punching the new number and stopping if there is none.
O2 (143)	Plot Axes and Points on the Cathode Ray Tube. 29 words. With this program one can plot a set of axes having marker intervals and can then plot points relative to the chosen origin.
X8 (144)	Assemble Blocks. 4 words. This brief routine is used with the Decimal Order Input (X1) for assembling blocks of a program without using specific K-directives. The first word of the first block is given and then reference is made to X8 before each block. The blocks are packed tightly and may be referred to in the program by S-parameters (beginning with S3) which are automatically inserted.
M6 (145)	Matrix Multiplication (Open) A kxj matrix B is read into the computer and then an ixk matrix is read one row at a time to form C =AxB, subject to the limitation kxj + k $\leq$ 936. The program contains checks on the scaling of the elements of C and on the number of elements in the rows of A and B.

The Illiac Library has been studied recently from the point of view of activity, and programs which are used only rarely have been placed in the auxiliary library. The program tapes for these seldom-used programs will still be as readily available as ever, but the programs will not be listed among those of the active library. Program tapes for obsolete programs will be withdrawn, as will be the active circulation of their descriptions. For example, Sum Check X7 will replace Sum Check X6 and the latter will not be listed in the future.

III. MACHINE USE.

The following list gives problem specifications for new problems which were tried in August. It does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 369.

NUMBER	PROBLEM SPECIFICATION	AFFILIATION
369	Profile validation of personality inventory (Thesis)	Psychology
370	Estimation of rainfall sampling variance	Ill. Water Survey
371	Diffusion equation (Thesis)	Chemistry
372	Fourth order central force	Physics
373	Earthquake response of multi-story building	Struct. Eng.
374	Factor analysis	Psychology
375	Eigenvalues and wave functions	Physics
376	Single degree of freedom system with combined impulses and applied forces with damping	Struct. Res.
377	Multi degree of freedom shear beam	Struct. Res.
378	Energy of formation of dislocation in NaCl	Physics
379	Electron lattice interaction in a model metal	Physics
380	Fourth order tensor forces	Physics
381	Matrix computation	C.S.L.
382	Photon difference tables	Physics
383	Pressure vessel stresses	Computer
384	Find pairs of error correcting codes	Computer
385	Efficiency of gamma-ray counter (Thesis)	Computer
386	Transient response of circular cylinder loaded by simulated end-on incidence of a shock wave	Struct. Res.
387	Find roots of a function	Physics
388	Evaluate definite integrals	Physics
389	Two-stage sequential screening	Education
390	Accuracy of an approximate method for determining the replacement curve	Struct. Res.
391	To find error correcting codes	Computer
392	Fourth order tensor force	Physics

In the eleven-month period October 1, 1953 to August 31, 1954 (during all of which time the Illiac was in operation) 192 problem specifications were received. The groups from which these came, together with the number from each group are shown below.

GROUP	NUMBER OF SPECIFICATIONS
Psychology Department	40
Physics Department	38
Digital Computer Laboratory	34
Structural Research Laboratory	26
College of Education	11
Electrical Engineering Department	10
Agricultural Economics Department	4
Institute for Juvenile Research	5
Dairy Science Department	2
Agronomy Department	2
Mechanical Engineering Department	1
Institute of Labor and Industrial Relations	1
Bureau of Economic Research	1
Physical Education Department	1
Marketing Department	1
Sociology Department	1
Illinois Water Survey	1
Astronomy Dept. (Indiana University)	1
Psychology Dept. (Indiana University)	1
Mechanical Engineering Dept. (Purdue University)	2
Control Systems Laboratory	2
Psychology Dept. (University of North Carolina)	1
Chanute Air Force Base	1
Chemistry Department	3
Institute of Communications Research	2

The number of problem specifications reveals nothing about the amount of Illiac time used. The work of the Psychology Department consists largely of problems in statistics and data reduction which require relatively small amounts of computation compared with the problems presented by engineers and physical scientists. This is indicated by the fact that of the approximately

2900 hours the Illiac was used for computation in the eleven-month period only about 200 hours, or about 7% were used by the Psychology Department for its 40 Problem Specifications. On the other hand, the Chemistry Department with only 3 Problem Specifications used about 250 hours, or about 9% of the available time.

Table I shows distribution of machine time for the month of August.

TABLE I

Eng. (8:00-12:00)	58:21
Eng. (Other times)	82:11
RAR	8:52
Leapfrog	45:46
Wasted	:42
Use of Computer by Departments	
Demonstrations	:32
Computer Group	39:30
Physics	67:25
Control Systems Laboratory	36:53
Structural Research	3:31
Structural Res. (AF-24994)	24:05
Structural Res. (Nobs-62250)	31:52
Psychology	7:27
Psychology (AF 25726A)	9:21
Elec. Eng.	1:08
Chemistry	43:46
Agriculture	10:27
Cosmotron	37:19
Indiana University	2:43
Chanute Air Base	4:50
Miscellaneous	16:46
Total	533:27

IV. COMMENTS ON THE MACHINE.

During the month, errors associated with the memory constituted a larger than normal amount of non-scheduled maintenance time. This makes the kind of error analysis sheet which has been presented before of less value in indicating the performance of the machine during the month. For this reason the error analysis sheet is not being included this month.

The trouble started with an indication of memory errors which occurred at isolated addresses but usually in the corners and usually on several cathode ray tubes at one time. While looking for this particular error, a serious fault occurred which is probably responsible for some of the later difficulties. This fault was observed as an arc in the gun structure in one of the cathode ray tubes. At the same time, the filament of that cathode ray tube was burned out and fell to the glass envelope and the tube lost its vacuum. Which of these was the original cause of the trouble is not known. As a result of the arc within this tube and the design of the filament and cathode circuits used for the tubes, four other tubes were damaged and were replaced. Even after this was done a number of errors occurred and some of these were believed to be due to cathode-to-heater breakdowns in some of the output tubes of regeneration chassis. In order to be sure that all of these tubes were satisfactory the machine was taken out of service for a period of about one day during which all of the tubes in the memory were checked and all of the circuits in the memory were cleaned. A number of tubes were also found to be bad in the output circuits of the address generator but it is not known whether or not these existed before the cathode ray tube arc or not. As a result of this tube testing and cleaning program this particular error in the memory was eliminated.

There were several occasions later in the month when a different memory error occurred. This error consisted each time of a change of about two rows of the memory raster from 0's to 1's on all of the cathode ray tubes. When this error first occurred it happened only very occasionally which added to the difficulty in finding it. By the end of August, the error was not found.

A check of Table I shows that the unscheduled maintenance time amounted to about 82 hours for the month. Except for the errors associated with the memory the number of the errors amounted to about 10 during the month. Two of these were associated with the dc power supplies.

V. RESEARCH ON COMPUTER COMPONENTS. (This work is supported in part by ONR Task 24.)

Direct Coupled Transistor Circuits

The shift register mentioned in last month's report was increased to three bits. With a selected set of transistors, error-less runs of more than two hours were obtained despite the fact that two of the junction transistors have a very low back resistance from base to emitter. However, it was found that an error had been made in the design of the flip-flop circuit. A new circuit was designed, and has been tested individually. A new register is being constructed using the modified flip-flop circuit.

A purely asynchronous shift register has been designed and will be built when additional transistors are received.

A flip-flop circuit using junction transistors and breakdown diodes was designed and tested. The junction transistors in the circuit are not saturated, but delay in changing the current through the diodes results in a triggering time of between two and three microseconds.

A report for ONR on the transistor circuit work is now being prepared.

Magnetic Core Buffer Memory for CSL

All of the operating chassis for the buffer memory have been built and checked against drawings. The principal technical work carried out during the month was associated with the circuits for and the procedure for testing the cores. A member of the CSL staff carried out the final test which easily provided enough cores for the memory. It has been decided to put in several extra memory columns in the core matrix so that if a broken core or some other difficulty is experienced with one of the columns, one of the spare columns can be used.

In checking the cores for this memory it was found that quite satisfactory reversible loops could be obtained using less than the normal number of 350 ma turns as originally planned. Thus it was found that it would be possible to operate the cores at 275 ma turns with no apparent instability in the reversible magnetic loop. The test circuits subjected the core under test to 4095 disturbing half-amplitude current pulses.

Magnetic Drum Memory

Late in July it was observed that use of the drum test code on one track caused intermittent reading errors. It was found that recording transients with all 1's recorded produced a low frequency variation of the base line as observed at the output of the playback amplifier. This base line difficulty was overcome temporarily by decreasing the time constant at the output of the last stage of the playback amplifier.

Noise signals were observed on several of the tracks. It was finally found that one of the 815's in a record amplifier had an open filament, with the result that the selected 815 record tube was not being cutoff during playback. Subsequently the record amplifier design was investigated and some design changes made.

The last two weeks of August were spent in studying the effects of record and playback switching transients on the playback amplifier. The efforts to improve the reliability of the drum storage system included the following:

1) A direct coupled amplifier was installed in the playback amplifier.

2) A diode clamping circuit to clamp the baseline to a fixed voltage during the second zero of each word was installed. It was found that clamping of the base line immediately following a switching transient adversely affected the base line during following words, to the detriment of the reliability of the system.

3) The effect of shortening the time constant at the input to the playback amplifier was studied. Experimentally it was determined that this time constant could not be shortened to improve the response of the playback amplifier to switching transients, since such shortening increased the overshoot of individual digit signals.

4) An RC network was employed to decrease the rate of change of signals supplied to the primary matrix. Voltage levels were set so that the output of the preamplifier to be selected was positive before the output of the previously selected preamplifier began to go negative. These changes reduced the size of switching transients as seen after the first RC network of the playback amplifier. The gain tolerance was improved when these circuits were installed.

Because the recording and playback heads for the present drum are not sufficiently uniform it has been decided that a new set of heads must be obtained in order to have satisfactory use of all the channels on the drum. Considerable investigation has been made of the possibility of buying a new set of heads for the present drum, but it now appears evident that both a new drum and a new set of heads should be purchased. The difficulties in mounting the new set of heads on a present drum are such that it appears undesirable.

VI. CONSTRUCTION.

All of the individual logical and operating circuits for the magnetic core memory have been finished. Some of the power circuits for turning on the ac and dc are still under construction. The framework for the magnetic core memory has been nearly finished and should be painted about the third week in September.

Although the major effort during the month has been on the magnetic core memory, additional construction work has included the following: installation of telephone system between the computer and the drum test unit, the mounting of a five-unit Brush pickup head for test on the magnetic drum, repair of two single-digit hand tape punches, repairs to some Teletype parts, completion of new chassis for the input-output rack for the Illiac, design work on the layout of a photoelectric tape comparer, a new main amplifier for the magnetic drum memory and cleaning and tube testing of the Illiac memory.

VII. PERSONNEL.

The personnel associated with the group and hence the contributors to this report are:

Bateman, Wm. E., Jr. Electronics Technician
Brown, Mrs. Caroline, Computer Teletype Operator (3/4 time)
Carter, Clifford E., Electronics Engineer for Illiac
Clark, Miss Helen B., Clerk-Stenographer III
Clements, Virgil F., Jr. Laboratory Mechanic
Cole, Douglas, Visiting Asst. Prof. of E.E. (Sept. 16)
Douglas, Alex. S., Visiting Asst. Prof. of Math. (Sept. 16)
Ehrlich, George, Jr., Engineering Draftsman
Farrington, Carl C., 1/2 time Res. Asst. (Sept. 20)
Fetzner, Mrs. Muriel, Computer Teletype Operator (Sept. 20)
Fishel, Jerome, Research Assistant
Frank, Werner, 1/2 time Res. Asst. (Sept 1)
Golub, Gene, Research Assistant
Gregory, R. T., 1/4 time Research Assistant

Hill, Robert, Student Assistant
Huffman, Wm. L., Computer Operator for Illiac
Kerkering, T.E., Sr. Laboratory Mechanic
Kudlich, R.A., Research Assistant
Lobaugh, Wm. R., Computer Operator for Illiac
Lopeman, H.E., Electronics Engineer for Illiac
Meagher, R. E., Chief Engineer
Metze, G. A., Research Assistant
Michael, Geo. W., Administrative Assistant
Miller, R. E., 1/2 time Research Assistant
Muerle, John L., Research Assistant
Muller, D. E., Res. Asst. Prof. of Applied Math.
Muroga, Saburo, Research Assistant
Nash, J. P., Res. Prof. of Applied Math.
Newmark, N. M., Chairman, Exec. Comm.
Ogata, Albert I., Student Assistant
Peck, George B., 1/2 time Research Asst. (Sept. 1)
Polivka, R. P., Research Assistant
Poppelbaum, W. J., Research Associate (Sept. 16)
Reynolds, Donald, Student Assistant (Sept. 1)
Robertson, J.E., Res. Asst. Prof. of Elec. Eng.
Russell, Miss Ramona J., Computer Operator for Illiac
Schneberger, Edward J., 1/2 time Res. Asst. (Sept. 1)
Seshu, Mrs. Lily, 3/4 time Research Assistant
Spandau, Kenneth L., Jr. Electronics Technician
Stephens, Allen, Asst. Laboratory Mechanic
Swire, B. E., Visitor (University of Sydney, Australia)
Taub, A. H., Res. Prof. of Applied Math. (On Sabbatical Leave)
Wenta, Joseph, Sr. Electronics Technician
Wier, J.M., Research Associate
Yu, Hwa-Nien, Research Assistant

The work of the group is under the administration of an Executive Committee with the following members: N. M. Newmark, Chairman, D. E. Muller, J. E. Robertson, J. P. Nash, A. H. Taub, and R. E. Meagher.

R. E. Meagher

R. E. Meagher

REM/hc

UNIVERSITY OF ILLINOIS
GRADUATE COLLEGE
DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

Teaching and graduate research are
not, in general, reported herein.

September 1, 1954 - September 30, 1954

I. MATHEMATICAL RESEARCH AND PROGRAMMING. (This work is supported in part by ONR Task 30.)

Boolean Algebra

Work is continuing in the investigation of metric properties of Boolean functions of 6 variables. The two interesting cases are for distances 8 and 16, and study of the former one was completed this month. The work was done relatively quickly by making use of symmetries exhibited in a new theorem which will be described in an internal report. The results of the distance 8 study indicate that exactly three new functions can be used to augment the net in this case. These three functions were predicted by a generalization of the results for distance 16 (see Internal Report No. 57.)

The methods which were used so effectively in the distance 8 case will now be used to complete the distance 16 investigation although they lose some of their efficiency in this case. Computer programs are now being prepared for this purpose.

Linear Algebraic Equations

Usually it is not necessary to solve linear equations using the Illiac's forty binary digits, and up to about fifty-five equations can be handled with the elimination method if half-precision numbers of twenty binary digits are used. This problem is now being studied and a program is being prepared.

Matrix Multiplication

The manipulation of matrices, while not occupying a major portion of computer time, contributes significantly to the number of small problems which are handled. A new closed routine for matrix multiplication is being checked. It contains most of the features of M6, the open routine.

Sine and Cosine

An improved sine-cosine routine has been developed which is shorter and faster than the old one and which has no restriction on the argument. The argument is given in the form $\frac{\theta}{\pi}$ by entering with $-1 \leq \frac{\theta}{2\pi} < 1$ and making use of the modulo 2 Illiac property in shifting left to give $\frac{\theta}{\pi}$ (mod. 2).

Floating Point Auxiliaries

The floating point routines have been rounded out with the addition of an arctangent auxiliary and by replacing the old natural logarithm auxiliary with a better one.

Drum Test Routines

A routine to test all possible combinations of preamplifiers with two playback amplifiers using all track locations was prepared. The routine is used to test reliability of playback under various gain tolerances by comparing a pseudo-random word played back from the drum with the corresponding word in the Williams memory. The routine is arranged in eight parts to allow the engineers considerable flexibility in its use.

II. LIBRARY ROUTINES.

During September the following five programs were added to the Illiac library. P11 and R4 were prepared by Mr. B. E. Swire of the University of Sydney, Australia.

C6 (146) Address Search. 23 words. This routine replaces C2 to which it is superior because words which are identically zero are skipped when address zero is being sought.

O3 (147) Display Numbers and Letters on the Cathode Ray Tube. 13 words plus one word for each type of character to be displayed. This is a closed routine and one character will be displayed (the time required is 40 milliseconds) each time it is entered. The character to be displayed is determined by the right-hand accumulator address upon entry, and the location of the character (lower left-hand corner) is given by the leftmost 16 accumulator digits. The programmer may choose either small (5 x 7) characters or large (10 x 14) characters when he reads in the routine, but he has no option after reading it in.

P11 (148) Rounded or Unrounded Point. 18 words. This routine is intended primarily for use in computations where results are given as an integer part followed by a decimal part. In such cases no sign is wanted for the decimal part, and round-off may cause an error. The two entry options give A rounded to n decimals with sign or A to n decimals without round-off and without sign.

R5 (149) Reciprocal. 17 words. This routine finds 1/A, putting the integer part in A and location 0 and the fractional part in Q and location 4.

M10 (153) Estimation of Communalities by the Method of Maximum Likelihood. Entire Program. This is a statistical program designed for estimation and tests of significance in factor analysis. The programmer uses four parameters: sample size, number of estimated factors, number of variables, and number of places to be printed. He then furnishes the necessary chi-square values, his correlation matrix R, and an estimation of a diagonal matrix G related to the communalities. The results printed are the latent roots (eigenvalues) of the matrix GRG after the first iteration, the chi-square criterion, the communalities and the significant factors.

III. MACHINE USE.

The following list gives problem specifications for new problems which were tried in September. It does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 393.

NUMBER	PROBLEM SPECIFICATION	AFFILIATION
393	Deuteron tensor force	Physics
394	Sixty-four digit error-correcting codes for distance 8	Computer
395	Characteristic expression of Boolean members	Computer
396	Product moment correlations (Thesis)	Psychology
397	Single degree of freedom system	Struct. Res.
398	Range straggling of high-energy electrons	Physics
399	Matrix inversion	Economics
400	Analysis of paired comparisons	Bur. Ed. Res.
401	Determination of motivation structure	Psychology
402	Photon shower study	Physics
403	Study of desired farm organization	Ag. Economics
404	Matching of factors (Thesis)	Psychology
405	Multiple correlation	Ag. Economics
406	Factor analysis	Bur. Ed. Res.
407	Farm budgeting by linear programming	Ag. Economics
408	Floating point logarithm auxiliary	Computer
409	Cathode ray tube display	Computer
410	Matrix multiplication	Computer
411	Track length distribution	Physics

Table I shows distribution of machine time for September.

TABLE I

Eng. (8:00-12:00)	60:04
Eng. (Other times)	67:23
R.A.R.	6:23
Leapfrog	44:10
Wasted	:21

Use of Computer by Departments

Computer Group	54:00
Cosmotron	10:51
C.S.L.	71:07
Physics	70:36
Struct. Res.	12:56
Struct. Res. (AF 24994)	30:47
Struct. Res. (Nobs 62250)	8:03
Psychology	7:48
Psychology (AF 25726A)	9:41
Electrical Engineering	4:40
Chemistry	18:29
Agriculture	23:47
Miscellaneous	6:18
Demonstrations	:06
Total	507:30

IV. COMMENTS ON THE MACHINE

Some memory trouble remained from the previous month which has made the number of service hours high during the month. The remaining memory difficulty was found to be due to one tube in the address generator. Many of the 6J6 tubes in the machine have been replaced with 5844 tubes.

V. RESEARCH ON COMPUTER COMPONENTS (This work is supported in part by ONR Task 24.)

Magnetic Core Buffer Memory for CSL

During the month the power wiring for both dc and ac has been completed. The wiring of the magnetic core matrix is progressing slowly. The cores have been wound in one direction but not in the other direction. Test of the circuits should start in the next two weeks.

Magnetic Drum Memory

A push-pull direct-coupled playback amplifier was installed in the experimental drum unit. Two new test codes were put into use. In one of these a random number of words consisting entirely of ones is recorded and then a previously recorded random number is read back and checked for correctness. This is used to produce record transients. In the other code a series of random words are read from the drum in a way such that all possible switching transients occur. Using these codes it is possible to make 8 tracks operate with a gain tolerance from low to high for any one track of about a factor of 2.0. Since all tracks do not have the same signal amplitude the overall gain tolerance is somewhat lower. Plans have been made to connect up a total of 64 tracks for use with the Illiac. Each track will have 32 words of 40 information digits. The 2048 words will then be used on a somewhat experimental basis until another drum unit is available.

Direct Coupled Transistor Circuits

A report on the work on transistor circuits has been prepared and is now being edited. Most of the work during the month has been on this report.

VI. CONSTRUCTION

Most of the construction work has been on the magnetic core memory unit. The case has been finished and the ac and dc power wiring has been finished. The work which remains includes: painting and installing of air duct connections, the addition of a transformer, remounting doors (which were removed for painting), all interconnections and about half of the wire threading for the core matrix.

A number of repairs and improvements were made to the tape handling equipment.

New chassis for the input-output rack of the Illiac were installed and placed in operation.

The ac turn-on for the drum was constructed and wired and three new playback amplifiers for the drum were built.

Work has been started on the parts for six new tape readers for tape handling purposes.

VII. REPORTS AND SEMINARS

Seminars

"A Proposed Order Code for EDSAC II," by A. S. Douglas, September 29, 1954.

VIII. PERSONNEL

The personnel associated with the group and hence the contributors to this report are:

Bateman, Wm. E., Jr. Electronics Technician
Brown, Mrs. Caroline, Computer Teletype Operator (until Sept. 20)
Carter, Clifford E., Electronics Engineer for Illiac
Clark, Miss Helen B., Clerk-Stenographer III
Clements, Virgil F., Jr. Laboratory Mechanic
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Ehrlich, George, Jr., Engineering Draftsman (until September 20)
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Muroga, Saburo, Research Assistant
Nash, J. P., Res. Prof. of Applied Math.
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R. E. Meagher
R. E. Meagher

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UNIVERSITY OF ILLINOIS
GRADUATE COLLEGE
DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

Teaching and graduate research are
not, in general, reported herein.

October 1, 1954 - October 31, 1954

I. MATHEMATICAL RESEARCH AND PROGRAMMING. (This work is supported in part by ONR Task 30.)

Boolean Algebra

Work has continued in the investigation of the augmented net of 6 variables and distance 16. New programs which were prepared for this investigation "found" a fifth function h which may probably be used to augment the net. It was then shown that no other functions of this type exist. The situation at present is as follows:

a. Three functions are known to exist which may be used to augment the net.

b. Two other functions are thought to possess this property and programs are now being run to determine whether they do.

c. If these five functions all possess the distance property then we know that no others do.

A general theorem was proved concerning systems having a given distance property and which are also closed under the operation of "exclusive or." Such a system, it was shown, can always be generated from a minimum set of points having minimum distance from zero.

Machine Interruption Routine

A routine is being prepared to make it easy to interrupt and resume computations. The programmer will specify the necessary memory locations to be printed out and these will be reset into the program when it is read in again. The program will then resume where it had left off.

Matrix Inversion

The present library routine for matrix inversion will handle only symmetric matrices and users wishing to invert a non-symmetric matrix A must form $C = A^T A$, invert C, and then form $A^{-1} = C^{-1} A^T$. This is awkward and slow, so a method following the Gauss elimination method is being studied.

Survey of Library Routines

A proper study of techniques for drum storage use requires a knowledge of characteristics of library routines. An analysis routine has been prepared which determines the following things for each library routine using the Decimal Order Input: total number of words; total number of terminating symbols F, L, S, N; number of addresses exceeding 64; number of addresses exceeding 128; total number of symbols read by the reader; number of pre-set parameters; number of order types. All but six library routines have been counted and results are now being tabulated.

II. ILLIAC LIBRARY.

The program library is being watched for activity, with little-used programs being placed in the auxiliary library. The most recent active list contains 78 programs, and there are about 75 others which are in the auxiliary library or which have become obsolete.

III. MACHINE USE.

The following list gives problem specifications for new problems which were tried in October. It does not indicate how the Illiac was used because large amount of machine time may have been consumed by problems with numbers less than 412.

NUMBER	PROBLEM SPECIFICATION	AFFILIATION
412	Error-correcting code search	Computer
413	Simultaneous equations to half precision	Computer
414	Solution of Poisson-Boltzmann equations	Phys. Chemistry
415	Job-information tests	Psychology
416	Transient response of circular cylinder to an end-on shock wave	Struct. Res.
417	Estimation of environmental effects upon milk production	Dairy Science
418	Electron accelerator and buncher spectrum curves	Elec. Eng.
419	Balance problems similarity analysis	Psychology
420	Farm income regression analysis	Agr. Econ.
421	Profit maximization of dairy plant	Agr. Econ.
422	Correlates of teacher-pupil perceptions	Bur. Ed. Res.
423	Three degree of freedom system with complex coupling	Struct. Res.
424	Efficiency of multiple random start systematic sampling	Computer
425	Boolean characteristic expressions	Computer
426	Maximum response of a single degree of freedom system	Struct. Res.
427	Information estimates for structural parameters	Agr. Econ.
428	Job knowledge pattern analysis	Psychology
429	Analysis of business fluctuations	Economics
430	Anxiety and problem solving	Bur. Ed. Res.
431	Damage pressure level for simple structures	Struct. Res.
432	Solution of $A-\lambda B = 0$ (Thesis)	Struct. Res.

Table I shows distribution of machine time for October.

TABLE I

Eng. (8:00-12:00)	47:06	
Eng. (Other Times)	12:50	
R.A.R.	7:12	
Leapfrog	52:02	
Wasted	:18	
Use by Departments		
Computer Group	66:27	
Classes	1:40	
Physics	31:04	
C.S.L.	56:32	
Struct. Res.	23:45	
Struct. Res. (AF 24994)	61:36	
Struct. Res. (Nobs 62250)	37:43	
Psychology	10:49	
Psychology (AF 25726A)	19:12	
Elec. Eng.	5:07	
Chemistry	33:13	
Agriculture	18:41	
Cosmotron	10:15	
Demonstrations	6:13	
Miscellaneous	8:30	
TOTAL		510:15

IV. RESEARCH ON COMPUTER COMPONENTS. (This work is supported in part by ONR Task 24.)

Magnetic Core Buffer Memory for C.S.L.

The magnetic core memory has been under test during this month. It has not had the core matrix inserted but by suitably faking input signals and stopping the pulser chain it is possible to go through all of the steps necessary to reading and writing without the matrix. This was done in a dc manner. One logical error was discovered which required no tubes to repair. In addition it was found that there is a too-long cathode follower chain which results in the excessive attenuation of a gate signal to the point where it will not operate the gate circuits. This seems fairly simple to repair. The sequencing of the operations themselves operates as planned. The core matrix is wired and is soon to be inserted into the unit.

Magnetic Drum Memory

Most of the work for the magnetic drum memory was directed toward putting into operation 64 tracks of 32 words each, amounting to a total of 2048 words. Most of the work has been finished except for testing and adjustments. The following table summarizes the status of the component parts which are necessary for the 2048 word memory but which have not been used in previous operations of the drum.

Chassis	Construction	Fil. Wiring	DC Wiring	Signal Wiring	Testing
6 Preamp chassis	0	3	3	2	1
1 5 Digit matrix	3	3	3	3	2
Matrix Amplifier	3	3	3	3	2
Inverter chassis and switching smoothing circuits	3	3	3	3	2

1 - Yet to be done
0 - Complete before Oct. 1
2 - Worked on, but not completed by Nov. 1
3 - Completed by Nov. 1

After visiting Engineering Research Associates and comparing their drum with that of the W. S. Macdonald Company and that of Librascope, Inc., it has been decided that the Engineering Research Associates drum appears to be most suitable for our needs. An ERA read-record head has been tested with our circuits.

It was found that at a spacing of 2 mils the response at 40 kc was 32 mv, at 80 kc it was 26 mv, and the ratio of peak response to lowest response from 3 kc to 80 kc was 1.27. For 1.5 mil spacing the response at 40 kc was 45 mv whereas that at 80 kc was 41.5 mv. The ratio of peak to lowest response at 1.5 mils from 3 kc to 80 kc was 1.12. These values indicate that for the present circuits a spacing of 1.5 mils is necessary to operate with the same gain values. There were indications that the surface of the drum was not being completely saturated but it is believed this will not occur for a drum with the red-oxide magnetic coating as this type coating is believed to require less flux for saturation. The tests of the head with the drum circuits gave a gain tolerance reading of nearly 2. This is approximately the same as found for the other heads so this does not seem to introduce any new difficulties.

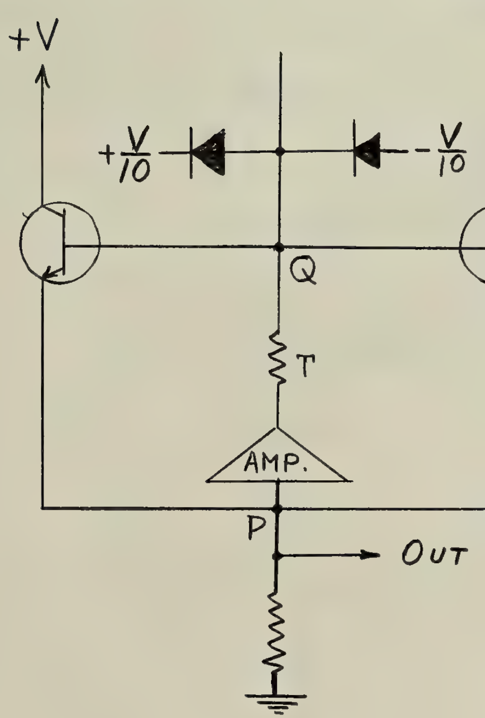
Direct-Coupled Transistor Circuits

The program in October had two principal goals: the design of a certain number of test instruments and a systematic study of the existing or possible transistor flip-flops.

The construction of the following instruments is now under way: an output characteristic tracer for point-contact transistor circuits which permits direct determination of the usefulness of a given unit in a given circuit,

a combination instrument which measures α, r_e, r_b, and r_c, a rack which will allow us to age 60 transistors for several hundred hours under closely controlled temperature conditions and which permits testing them without removal from the rack.

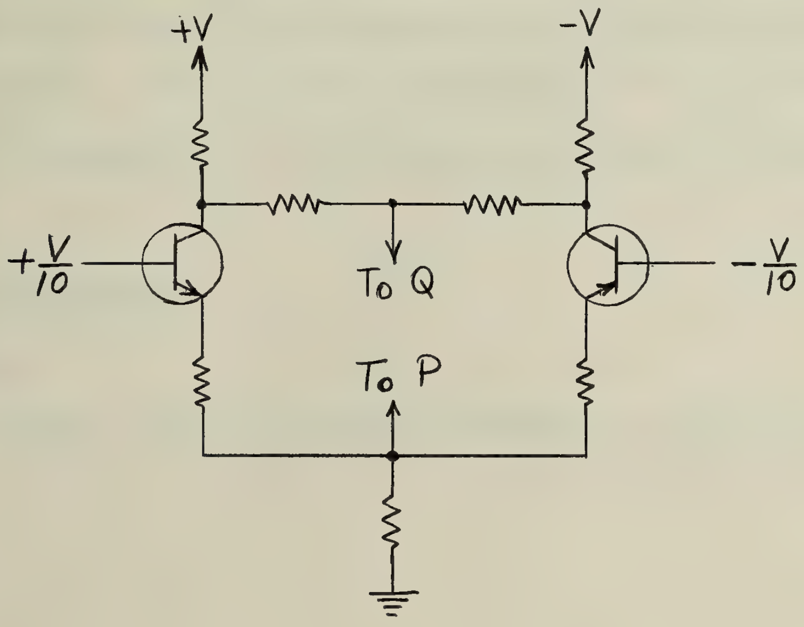
As regards the flip-flop circuits we have, for the moment, ruled out the existing junction-transistor devices of the Eccles-Jordan type (because of their slowness) and the point-contact circuits (because of their poor reliability). A new circuit was designed, using a npn and a pnp unit having a common emitter resistor and a common base connection. A non-saturating amplifier is connected between the emitter and base leads. The circuit is given in the adjoining figure and operates as follows:



When the common base lead is positive with respect to ground, the left hand unit conducts and P follows the potential of Q. Now the potential of Q is a multiple of that of P (without phase inversion) and the "race" between the two voltages ends only when the limit set by diode D_1 is attained. Then the diode draws a heavy current through r and the voltage difference between P and Q is only the-nearly constant-emitter drop.

The same reasoning applies to a negative excursion of the base, limited this time by D_2. As this flip-flop uses only emitter followers (non-saturating by their nature) and a linear amplifier with limited input swing, there can be no saturation and consequently no switching delay by electron--or hole--storage effect.

In practice this circuit proved to be as fast as point-contact devices without exhibiting their unreliability; it can be used with a wide range of junction transistors. The switching time for trigger pulses having the amplitude of the output signal is less than 1 μs. The dc-amplifier used in the circuit is given in the figure below:



The use of two parallel units (one pnp, the other npn) has the advantage that the voltage divider between the two collectors gives zero voltage at Q for grounded input without reducing the voltage swing of the amplified signal. Furthermore the temperature change of the bias currents produces no drift.

We are adapting gating circuits to the above device which will give a "floating output" as long as no "gate" signal is present. It is hoped that in the near future a double-shift register using the new circuits will be in operation.

V. CONSTRUCTION

The work on the magnetic core memory unit by the shop has been completed. Six new paper-tape readers are in the process of construction as reported last month. Approximately fifteen more parts for each of the new readers has been completed. A film cassette to be used with the cathode ray tube camera which will hold about one hundred feet of film and have facilities for automatic winding and for cutting off the film is nearly completed. Smaller amounts of work were carried out on additional test facilities for the tape readers, three chassis for the tape comparer unit which is to be built, three chassis for transistor test circuits, repairs and servicing to the Teletype equipment, and rearrangement of the storage space in both the storeroom and the basement.

VI. REPORTS AND SEMINARS.

Reports

"A Bound on Error in General Quadrature Formula with Equidistant Ordinates," Report No. 59, October 20, 1954, Robert T. Gregory

Seminars

"Library Subroutines on the Drum," October 6, 1954, Raymond P. Polivka

"Use of the UNIVAC in Linear Programming," October 13, 1954 Werner D. Kahn

"Algebraic Methods for Constructing Error Correcting Encoding Systems," October 20, 1954, David E. Muller and Saburo Muroga

VII. PERSONNEL.

The personnel associated with the group and hence the contributors to this report are:

Bateman, Wm. E., Jr. Electronics Technician
Carter, Clifford E., Electronics Engineer for Illiac
Clark, Miss Helen B., Clerk-Stenographer III
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Huffman, Wm. L., Computer Operator for Illiac
Kerkering, Thomas E., Sr. Laboratory Mechanic
Lobaugh, Wm. R., Computer Operator for Illiac
Lopeman, Harold E., Electronics Engineer for Illiac
Meagher, R. E., Chief Engineer
Michael, George W., Administrative Assistant
Miller, Raymond E., 1/2 time Research Assistant
Muller, David E., Res. Asst. Prof. of Applied Math.
Muroga, Saboro, Research Assistant
Nash, J. P., Res. Prof. of Applied Math.
Newmark, N. M., Chairman, Exec. Comm.
Ogata, Albert I., Student Assistant
Peck, George B., 1/2 time Research Assistant
Polivka, Raymond P., 1/2 time Research Assistant
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Pelg, Edmund, Jr. Electronics Technician
Reynolds, Donald, Student Assistant
Robertson, James E., Res. Asst. Prof. of Elec. Eng.
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Schneberger, Edward J., 1/2 time Research Assistant
Seshu, Mrs. Lily, 1/2 time Research Assistant
Stephens, Allen, Asst. Laboratory Mechanic
Swire, B. E., Visitor (University of Sydney, Australia)
Taub, A. H., Res. Prof. of Applied Math.
Wenta, Joseph, Sr. Electronics Technician
Wier, Joseph M., Research Associate (3/4 time)
Yii, Roland H.C., 1/2 time Research Assistant
Yu, Hwa-Nien, 1/2 time Research Assistant

The work of the group is under the administration of an Executive Committee with the following members: N. M. Newmark, chairman, D. E. Muller, J. E. Robertson, A. S. Douglas, J. P. Nash, A. H. Taub, and R. E. Meagher.

R.E. Meagher.
R. E. Meagher

REM/hc

UNIVERSITY OF ILLINOIS

GRADUATE COLLEGE
DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

Teaching and graduate research are
not, in general, reported herein.

November 1, 1954 - November 30, 1954

I. MATHEMATICAL RESEARCH AND PROGRAMMING. (This work is supported in part by ONR Task 30.)

Drum Programming

Modification of Library Routines N2 and N4 have been made to permit recording on the magnetic drum of sequences of decimal fractions and integers which are punched on tape. Library Routine N1 needs no modification because it reads one fraction at a time and thus may be followed with a drum record order.

Simultaneous Linear Equations

A half-precision routine for solving sets of linear algebraic equations has been checked. It gives results to at most 5 decimal places for a maximum of 53 equations. The maximum time required is about 5 minutes.

Fourier Series

A routine has been checked for finding the Fourier sine or cosine series expansion of a function.

Cathode-Ray Tube Output

An improved display routine is being written which will allow the use of ordinary punch output routines with the cathode-ray tube and which will give the programmer considerable flexibility.

II. LIBRARY ROUTINES

During the month of November the following programs were added to the Illiac library.

To the active library were added:

A 6 (154) Floating Decimal Routine and Auxiliaries. 467 words. This program furnishes a machine user with Library Routines A 1, A 3, RA 1, TA 1, SA 2, TA 2, and SA 3 and

provides him with parameter entries to them. Thus many problems can be quickly programmed and run in floating decimal arithmetic.

E 2 (158) Integration by Simpson's Rule. 21 words.

This routine requires 1.4n + 3.2 milliseconds to evaluate Simpson's rule for a tabulated function of n values. (This was programmed by Mr. L. M. Isaacson of the Department of Chemistry and Chemical Engineering.)

M 11 (160) Matrix Multiplication (Closed). 77 words.

The product AB = C is formed with C retained in storage. The routine may be entered with neither A nor B in storage or with B in storage. Checks are incorporated to make sure that c_{ij} does not exceed capacity (the program is for fixed point numbers) and that all rows of a matrix being read into the Illiac have the same number of elements. If we form $c_{ij} = a_{ij}\ b_{jk}$, the number of locations required for matrix elements is k + kj + ij. The time to multiply a pair of 20 by 20 matrices with 10 decimal place elements when both must be read into the Illiac is about 40 seconds.

J 1 (159) Roots of a Polynomial. Complete Program.

This program accepts a data tape which has polynomial coefficients (real or complex) listed in floating decimal form. The roots are printed similarly together with a residual obtained by substituting the root back into the original equation. A third-order process is used, and the

time required is about $18 + 5n + 0.08n^2$ seconds, where n is the order of the polynomial. Accuracy depends upon condition of the polynomial but is usually about 9 decimal places.

0 4 (161) Fast Fraction Display, 4 by 6 Raster. 68 words. Requiring about 11 milliseconds per digit, this program displays on the cathode-ray tube the number in the accumulator. The location of the lower left hand corner of the first character displayed is determined by the leftmost 16 binary digits of Q.

0 5 (162) Fast Character Display, 4 by 6 Raster. 50 words for 0, 1, 2,...9, +, - . 58 words for 0, 1, 2, ...9, K,...L. This routine is similar to 0 4 but entry is different. The first 16 binary digits of the accumulator define the position of the lower left hand corner of the character and the right hand address position in the accumulator defines the character n, $0 \leq n \leq L$. With this format and close spacing 1600 characters can be displayed in one frame.

SA 3 (155) Natural Logarithm Auxiliary. 30 words. This is a floating point auxiliary which in 15 milliseconds gives the logarithm of the number in the floating accumulator with a maximum error of 1 unit in the 9th decimal place.

TA 2 (156) Arc Tangent Auxiliary. 48 words. Starting with the number in the floating accumulator, this routine requires 15 milliseconds to produce the arctangent with a possible error of 1 unit in the 9th decimal place.

T 5 (157) Sine-Cosine Routine. 21 words. This program, given θ/π in A, places $(\sin\theta)/2$ in A. Because of the overflow properties of the Illiac the result is unaffected by overflows of θ/π from left shifts or additions. A Tchebyscheff polynomial expansion is used to give the sine in 9 milliseconds with an error not greater than 2^{-38}.

To the auxiliary library were added:

M 7 (150) Principal Axes Factor Analysis. Complete Program. This is a modification of Library Routine M 3, and it prints the eigenvectors scaled by the square root of the corresponding eigenvalue. (The modification was made by Mr. J. O. Neuhaus of the Department of Psychology.)

M 8 (151) Sums of Squares of Rows and Columns. Complete Program. This program forms sums of squares of the rows and columns of a matrix. In a matrix with r rows and c columns the capacity of the routine is defined by $2r + c < 920$. (This program was also written by Mr. Neuhaus.)

M 9 (152) Square Root Factorization. Complete Program. This program uses the square root method to factor a given correlation matrix. (The program was written by Mr. R. J. Twery of the Department of Psychology.)

III. MACHINE USE.

The following list gives problem specifications for new problems which were tried in November. It does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 433.

NUMBER	PROBLEM SPECIFICATION	AFFILIATION
433	Analysis of schizophrenic word associations (Thesis)	Psychology
434	Memory read-out	Computer
435	Intercorrelation of teacher and pupil characteristics	Bur. Ed. Res.
436	Hoarding behavior in the rat	Bur. Ed. Res.
437	Factorial analysis of variance	Agronomy
438	First excited state of helium	Physics
439	A search for the root of $f(x) = 0$	Struct. Res.
440	Farm budgeting linear program	Agr. Econ.
441	Exact solution of interaction	Struct. Res.
442	Factor analysis of personality tests	Psychology
443	Investigation of factorial stability	Psychology
444	Complex roots of 12 algebraic equations	Mathematics
445	Least squares fit	Physics
446	Lattice design analysis of variance	Agronomy
447	Fourier analysis	Computer
448	Probability of response to multiple choice test items	Education
449	Analysis of variance on corn performance tests	Agronomy
450	Tensor potential with a Gaussian (Thesis)	Physics
451	Matrix inversion	Psychology
452	Quartimax analysis	Medical Col.

Table I shows distribution of machine time for November.

TABLE I

Maintenance and Illiac Eng. (usually 8:00 a.m. - 12:00)	45:10
Unscheduled Maintenance or Repair	6:35
Drum Eng.	9:18
R.A.R.	6:40
Leapfrog	44:15
Wasted	:11

Use by Departments

Computer Group	46:49
Classes	13:05
Physics	22:27
C.S.L.	101:48
Struct. Res.	21:41
Struct. Res. (AF24994)	24:43
Struct. Res. (Nobs 62250)	34:50
Psychology	8:08
Psychology (AF 25726A)	4:38
Elec. Eng.	:55
Chemistry	19:57
Agriculture	21:01
Cosmotron	32:14
Ind. U.	1:04
Demonstrations	1:07
Miscellaneous	12:39
TOTAL	479:15

IV. RESEARCH ON COMPUTER COMPONENTS. (This work is supported in part by ONR Task 24.)

Magnetic Core Buffer Memory for C.S.L.

This memory has been almost completed during the month. The control was completely checked out along with certain of the drivers. It was also found necessary to make a wiring change in the column drivers and because of this in the driver drivers due to a logical error in the design. This has been done and now this all operates satisfactorily. At the present moment it is possible to read out and to write into any of the 1920 cores without any obvious difficulty. During the period a circuit was designed and built which enables one to sequence the reading and writing operations one after the other with a suitable delay interposed such that it is possible to observe the output signals and other pertinent ones without harming the pulse portions of the circuit. This same chassis also enables a one-shot read or write operation. This was used to check and see if there were any bad cores in the matrix. It was found that one of the cores that was wired in was wired in one dimension only and so rather than do any rewiring, one of the spare columns was used. Currently the testing is at the point where hammer testing seems close at hand to weed out any bad joints that may exist which have not turned up as yet.

Magnetic Drum Memory

During this month the wiring of the drum unit for expansion from 8 to 64 tracks (2048 words) was completed. The setting of the bleeder resistors was completed on 8 tracks and oscillations were eliminated on some of the dc busses throughout the test unit by bypassing the busses to ground with .01 μfd condensors. Gain tolerance tests on these eight tracks while

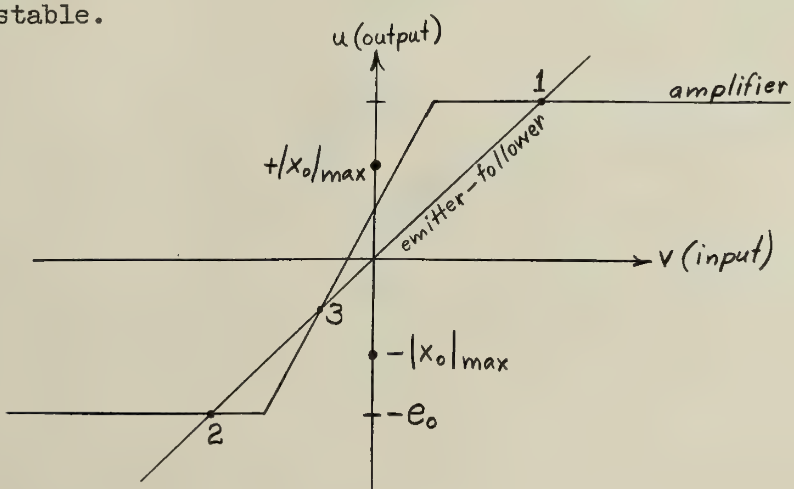
operating from the computer with the drum test code indicated the operating conditions were approximately the same as previous measurements by this method.

Leads between the drum word counter to Illiac order register were permuted so that successive Illiac addresses correspond to every fourth drum word.

A type 1100 drum with heads was ordered from ERA.

Direct-Coupled Transistor Circuits

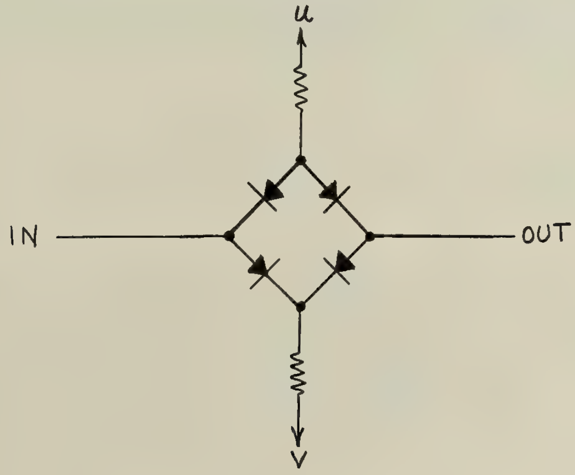
The work on the new type of flipflop (described in the last report) has absorbed the major part of the time of the transistor circuit group during November. In particular an exact theory and a tolerance analysis of the device have been worked out. As was expected, the variation of parameters in the emitter follower circuit has no influence on the performance: the input-output voltage characteristic of this part is always a straight line of slope one passing through the origin. The behavior of the amplifier section can be represented by a line having a minimum slope μ_o and passing through a point on the segment $-|x_o|_{max}$ to $+|x_o|_{max}$ of the u-axis (see figure). After hitting the lines $u = +e_o$ and $u = -e_o$, the action of the clipping diodes bends the amplifier characteristic round into a horizontal line. The 3 possible states of the flipflop are given by the points of intersection of the emitter-follower and the amplifier characteristic. It can be proved that state 3 is always unstable, 1 and 2 always stable.



It can be seen that the two stable states 1 and 2 are independent of the amplifier gain μ and the amplifier drift x_o as long as $|x_o| < |x_o|_{max} < e_o$ and $\mu \geq \mu_o = (e_o + |x_o|_{max})/e_o$. It is possible to find a circuit satisfying these two requirements plus the non-saturation condition (which turned out to be of secondary importance: only one transistor can saturate at the time). This circuit allows for 5% simultaneous variation in resistors, supply voltages and current amplification factors and for 100% variation in the bias current i_{co} of the transistors.

A packaged unit has been built using the optimum values. This will be the basis of a shift-register to be constructed next month. For this register we have attached a neon-bulb read-out circuit to the flipflop as well as "clear to 0" and "clear to 1" inputs.

After having examined a certain number of gating circuits, it was found that the diamond shaped device (see figure) gave the most reliable results: for u > v it gates, for u < v input and output float. A pulser has been built to drive these gating circuits. It has two alternate series of output pulses, each series being available with positive and negative polarity simultaneously. The repetition rate is of the order of 15 μs and the minimum pulse width ~ 3 μs. A detailed technical report is in preparation.



V. CONSTRUCTION

Thirteen more parts for each of six of the high speed tape readers have been built. Additional parts have been constructed for a film cassette which will make it possible to hold about 100 feet of film for the output of the cathode-ray tube unit. The core board for the MCM unit was wired in place and a number of changes and corrections were made to the MCM unit. A chassis for the purpose of displaying the N curves of point contact transistors was constructed.

VI. REPORTS AND SEMINARS

Reports

"A Study of Some Direct-Coupled Asynchronous Computer Circuits Using Transistors," October, 1954, Robert A. Kudlich and Hwa-Nien Yu.

"On the Convergence Rate of an Iterative Process," Report No. 60, November 5, 1954, Robert T. Gregory.

"Determination of Flows Behind Stationary and Pseudo-Stationary Shocks," A. H. Taub.

Seminars

"Finding the Zeros of a Polynomial on the Illiac," November 3, 1954, D. E. Muller

"Determination of Flows Behind Stationary and Pseudo-Stationary Shocks," November 10, 1954, A. H. Taub

"System Design and Order Code of the C.S.I.R.O. Mark I Computer," November 17, 1954, B. E. Swire

VII. PERSONNEL

The personnel associated with the group and hence the contributors to this report are:

Breed, Charles P., Draftsman (Started Nov. 15)
Bateman, Wm. E., Jr. Electronics Technician
Carter, Clifford E., Electronics Engineer for Illiac
Clark, Miss Helen B., Clerk-Stenographer III
Clements, Virgil F., Jr. Laboratory Mechanic
Cole, Douglas, Visiting Asst. Prof. of E. E.

Douglas, Alexander S., Visiting Asst. Prof. of Math.
Farrington, Carl C., 1/2 time Research Assistant
Fetzner, Mrs. Muriel, Computer Teletype Operator
Fishel, Jerome, 1/2 time Research Assistant
Frank, Werner L., 1/2 time Research Assistant
Golub, Gene H., 1/2 time Research Assistant
Gregory, Robert T., 1/2 time Research Assistant
Hill, Robert S., Student Assistant
Huffman, Wm. L., Computer Operator II
Kerkering, Thomas E., Sr. Laboratory Mechanic
Lobaugh, Wm. R., Computer Operator I.
Lopeman, Harold E., Electronics Engineer for Illiac
McGinnis, Gerald A., Sr. Elec. Tech. (Started Nov. 9)
Meagher, R. E., Chief Engineer
Michael, George W., Administrative Assistant
Miller, Raymond E., 1/2 time Research Assistant
Muller, David E., Res. Asst. Prof. of Applied Math.
Nash, J. P., Res. Prof. of Applied Math.
Newmark, N. M., Chairman, Exec. Comm.
Ogata, Albert I., Student Assistant
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Pelg, Edmund, Jr. Electronics Tech.
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Poppelbaum, W. J., Research Associate
Reynolds, Donald, Student Assistant
Robertson, James E., Res. Asst. Prof. of Elec. Eng.
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R. E. Meagher
R. E. Meagher

REM/arf

UNIVERSITY OF ILLINOIS

GRADUATE COLLEGE

DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

Teaching and graduate research are
not, in general, reported herein.

December 1, 1954 - December 31, 1954

I. MATHEMATICAL RESEARCH AND PROGRAMMING. (This work is supported in part by ONR Task 30.)

Drum Programming

With 2048 words of drum storage now in use, a preliminary set of routines is being made available to Illiac users. These routines will record and play back with minimum access speeds after the first entry and include sum checks to verify correct transfer between drum and Williams memories.

Matrix Inversion

As a part of this problem a routine has been prepared to find the rank and determinant of a matrix and to triangularize the matrix.

Simultaneous Linear Equations

The problem of solving large sets (up to 160 equations) of linear algebraic equations is being studied. At present consideration is being given to the elimination method.

Boolean Algebra

An attempt has been made to reformulate the Boolean difference equations representing a dynamic circuit

$$\Delta Z_i = f_i(Z_1, Z_2 \ldots Z_n)$$

so as to indicate which circuits will yield consistent results regardless of time considerations. This is done by introducing new variables $X_1, X_2, \ldots X_m$ where the Z's are contained among the X's. Then the above equations are written

$$\Delta X_i = g_i(X_1, \ldots X_m)$$

where the expression for g_i may contain no argument more than once. A condition that the circuit will behave independently of time considerations may then be stated as $\Delta X_i \Delta X_j = 0$ whenever X_i and X_j appear in the same function g_i.

Data Processing

Two routines for finding autocorrelations have been tried. One, limited to about 790 numbers, uses only the Williams memory. The other uses the drum.

II. LIBRARY ROUTINES.

During the month of December the following five programs were added to the active Illiac library. Those marked "preliminary" will not be distributed until they have been used enough to see whether modifications are desirable.

L5 (165) *Half Precision Automatic Linear Equation Solver. Entire Program.* This program will solve up to 51 simultaneous linear algebraic equations with an accuracy of not more than 5 decimal places. The elimination method is used. Maximum time is about 5 minutes.

N5 (167) *Drum Fraction Input. 28 words. PRELIMINARY.* This program requires 14 milliseconds per character to read a sequence of signed decimal fractions having up to 12 decimal places each from the tape and place them in successive magnetic drum locations.

N6 (168) *Drum Integer Input. 19 words. PRELIMINARY.* Using 12 milliseconds per character, this program will place in successive magnetic drum locations a sequence of signed decimal integers (with up to 12 digits each) read from the tape.

C7 (163) *Drum Sexadecimal Post Mortem. 23 words. PRELIMINARY.* This routine overwrites the Decimal Order Input routine and prints in sexadecimal form the contents of successive drum locations specified by a parameter which gives the first of ten locations to be printed.

C8 (164) *Drum Fraction Post Mortem. 29 words. PRELIMINARY.* This routine occupies locations 995-1023 and prints signed 12-place decimal fractions from sets of 10 drum locations as specified by a parameter.

III. MACHINE USE.

The following list gives problem specifications for new problems which were tried in December. It does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 453. Numbers followed by T are thesis problems.

NUMBER	PROBLEM SPECIFICATION	AFFILIATION
453 T	Calculation of table	Elec. Eng.
454	Motivation study	Psychology
455	Children's interfactor study	Psychology
456	Frequency spectrum	Control Sys. Lab.
457	Attitude change of German students	Inst. Labor and Ind. Relations
458	Comparison of centroid and principal axes factor analysis	Psychology
459	Commutation study	Elec. Eng.
460	Tables of ∅-functions	Mech. Eng.
461	Spacial perception test	Psychology
462	Multi-degree of freedom shear beam with damping	Structural Res.
463	Memory reset	Computer
464	Matrix diagonalization	Computer
465 T	Least squares diffusion data	Chemistry
466	Factor analysis and rotation	Psychology
467 T	Fourth order central potential	Physics
468	Factor rotation	Inst. Comm. Res.
469	Solution of 26 simultaneous non-linear algebraic equations	Structural Res.
470	Predicting the hardness of steel	Computer
471 T	Deuteron triplet state	Physics
472	Roots of a polynomial	Elec. Eng.
473	Roots of a polynomial	Elec. Eng.
474 T	Fourth order singlet force	Physics
475	Comparison of factor structures for responses on job-attitude items	Psychology

NUMBER	PROBLEM SPECIFICATION	AFFILIATION
476	Electron emission from a hollow cathode	Elec. Eng.
477	A learning model random walk	Harvard Univ.
478	Conductivity in anisotropic thin films	Physics
479 T	Buckling of arches	Theoretical and Applied Mech.
480	Reliability of pupil rating of teachers	Bur. Ed. Res.

Distribution of machine time for the month of December is shown in Table I.

TABLE I

Maintenance and Illiac Engineering (usually 8:00 A.M. - 12:00 N)	46:27
Unscheduled Maintenance or Repair	10:32
Drum Engineering	33:57
R.A.R.	8:24
Leapfrog	67:14
Wasted	:08
Computer Use by Departments	
Computer	13:54
Classes	16:54
Physics	32:44
C.S.L.	54:40
Struct. Res.	26:08
Struct. Res. (AF 24994)	28:06
Struct. Res. (Nobs 62250)	22:19
Psychology	12:42
Psychology (AF 25726A)	8:29
Electrical Engineering	9:09
Chemistry	13:08
Agriculture	19:44
Cosmotron	28:30
Indiana University	9:09
Harvard University	1:32
Miscellaneous	21:28
Total	485:18

IV. COMMENTS ON THE ILLIAC AND RELATED FACILITIES.

The Illiac had a total of 39 interruptions or errors during the month. Nineteen of these occurred during the reading of tapes into the machine. Four of the interruptions were due to punching troubles but of these, three were due to clogging of the chad chute. Sixteen other interruptions or errors occurred from all other causes, including six errors for which "reason unknown" was listed and no good information is available on these errors. Included in the total number of errors or interruptions of 39 there were nine leapfrog errors in 38 hours of leapfrog time. Three of the nine leapfrog errors were due to various punching troubles. There were about ten hours of unscheduled maintenance and a total operating time of about 485 hours.

The auxiliary drum memory with 2048 words of forty binary digits has been made available to programmers on an experimental basis.

Additional Teletype equipment has been received and this will eventually supplement that now available for tape preparation. Included is another keyboard perforator which is ready to be used, a model 28 page printer which prints approximately ten characters per second and three BRPE-2 punches which punch sixty characters per second. The page printer and punches require some work to be incorporated into the Illiac facilities. One of the BRPE-2 punches will be used as Illiac output to replace the present twenty-character-per-second punch.

V. RESEARCH ON COMPUTER COMPONENTS. (This work is supported in part by ONR Task 24.)

Magnetic Core Buffer Memory for C.S.L.

During this period the magnetic core memory has been completed, tested, and the necessary drawing changes given to the draftsman. The testing was done with an automatic checking circuit recycling a 101010......1010 pattern through the memory, checking at the serializing point for errors. Runs of 48 hours, 30 hours, 36 hours, and 45 hours without error were made. All errors after the first test was begun were due to bad tubes and not due to storage errors. The temperature tolerance was checked by removing the cooling and allowing the temperature to rise to 65°C. This would correspond to operating

the device when the outside air temperature was about 58°C. No errors were made during the test, indicating a wide temperature tolerance. All power supplies were moved by ±5%. Storage was error-free. Raising the -300v to -285v and the +150v to 157.5v caused the device to hang up although no error resulted in storage. In the near future it is hoped that the completed circuit book will be ready.

Magnetic Drum Memory

A new drum test code was written and put into use. Beginning at a random location, a random number of random numbers are recorded at successive slots around the drum periphery on random tracks. The same numbers are then played back and checked against the numbers originally recorded. Results indicate that the new drum test code is more stringent than the code previously used.

A test unit to test drum and head signals for the new drum was designed. This is shown on Drawing L614. This unit contains the circuits to record on one track at a time for one revolution of the drum at either 40 kc or 80 kc and with varying record currents and varying clamping resistor sizes, and an amplifier for an origin pulse from the drum.

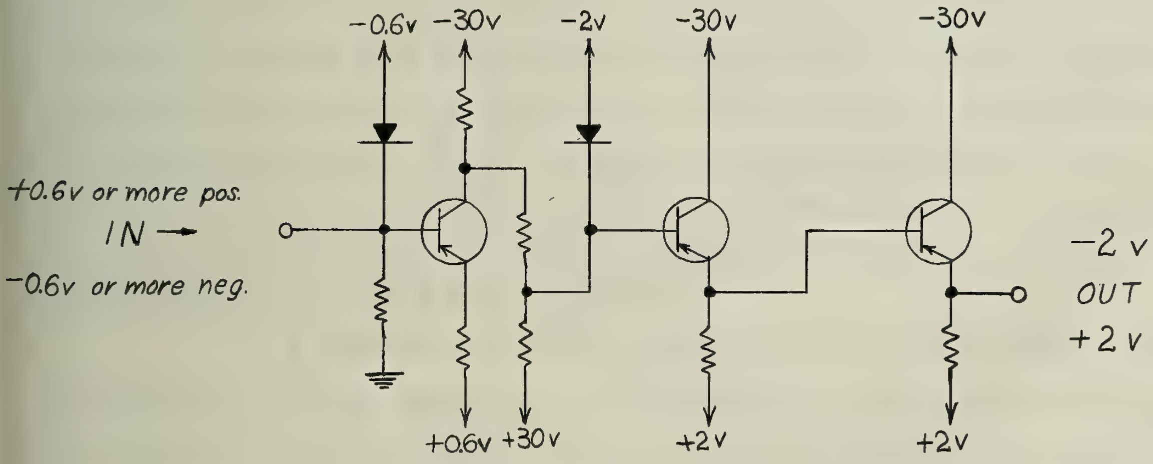
Direct-Coupled Transistor Circuits

The npn-pnp flipflop was again the center of attention in December. In particular, tests were conducted on a packaged unit to find out how the device behaves in continuous service. It was found that pulse service ($2x10^5$ changes of state per second)for eight hours and static service (one state) for twenty-four hours of operation did not appear to modify the characteristics of the unit.

A technical report on the flipflop is now being prepared. In it the following points are examined: simplified equations for npn and pnp transistors at low and high frequencies, theory and stability analysis of the new flipflop, tolerance analysis and general design considerations.

A four bit double shifting register using the new flipflop is under construction and will probably be put into service by the beginning of January. It will allow us to run eight flipflops continuously.

A great deal of time has been spent looking into a reliable not circuit and a signal level-restoring circuit. A possible not circuit was obtained by using the design in the figure below. The design features a double emitter-follower output and clipping diodes for the output signal. The first stage is calculated in such a way that under all drift conditions the overswing is sufficient to guarantee the full output amplitude of 2v with input signals as low as 0.6v. It turns out that economically a double emitter-follower is not more expensive than a single stage, because the latter necessitates a very high α transistor. The level-restoring circuit makes use of a grounded-base amplifier, driven by and working into an emitter-follower.



A Proposed Not Circuit

Preliminary investigations were conducted to examine the possibility of using high-current transistors for power stages. It is thought that this would be of considerable interest if a magnetic core type of memory is to be attached to a transistorized computer.

An instrument which traces automatically the input characteristic (N-curve) of point-contact transistors was tested and put into service. It features several resistance decades which allow the operator to simulate the different circuits which may be used. The output circuits of the instrument are dc-coupled and it is possible to read directly on the oscilloscope the voltages corresponding to the peak and valley points. A bunch of twenty

transistors was examined and a large variation of the position of the N-curve from one unit to the other was observed. A more systematic study, taking account of aging, will me made later.

VI. CONSTRUCTION.

A total of fifty parts for each of six new readers has been finished. Two of these readers will be used with a high-speed tape comparer unit which is intended to be installed in the Teletype Room. Reader "C" has been altered to contain a larger motor and other improved driving facilities so that it should be comparable to readers "D" and "E" in this respect. A rather considerable amount of effort has been put into reader "D" which has been the largest source of reader errors during the month. A new roller was installed together with a hard rubber driving drum in order to improve the tape-pulling even when the brake is set rather tightly. The light holes have been made smaller by filling them with silver solder and redrilling them. It is believed that the "fifth hole" was somewhat too large and that this in turn caused some of the errors experienced with this unit. Phototubes with uniform sensitivity have been installed.

A test unit has been built with two rotary brushes, the purpose of which is to clean tape before it is admitted to the tape reader. It can be connected into the reader circuit so that the brushes stop rotating when the tape stops and start when the tape starts. This unit is being tried experimentally to see if it can keep the tapes cleaner and hence reduce the number of errors during input to the machine.

A temporary test rack is being assembled to test the circuits of the photoelectric tape comparer unit. Four chassis built from Drawings 527, 531, and 532 have been built and are installed in the test rack.

VII. REPORTS AND SEMINARS.

Seminars

"Arithmetic Unit Design for Binary and Binary-Decimal Digital Computers," Prof. James E. Robertson, December 1, 1954.

"Determination of Flows Behind Stationary and Pseudo-Stationary Shocks," Prof. A. H. Taub, December 8, 1954.

Seminars

"Determination of Flows Behind Stationary and Pseudo-Stationary Shocks," Prof. A. H. Taub, December 15, 1954. (Continuation of former seminar)

VIII. PERSONNEL.

The personnel associated with the group and hence the contributors to this report are:

Allen, Guy, Computer Operator I (Starting January 1)
Breed, Charles P., Draftsman
Bateman, Wm. E., Jr. Electronics Technician
Carter, Clifford E., Electronics Engineer for Illiac
Clark, Miss Helen B., Clerk-Stenographer III
Clements, Virgil F., Jr. Laboratory Mechanic
Cole, Douglas, Visiting Asst. Prof. of E. E.
Douglas, Alexander S., Visiting Asst. Prof. of Math.
Farrington, Carl C., 1/2 time Research Assistant
Fetzner, Mrs. Muriel, Computer Teletype Operator
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Huffman, Wm. L., Computer Operator II
Kerkering, Thomas E., Sr. Laboratory Mechanic
Lobaugh, Wm. R., Computer Operator I. (terminating Jan. 7)
Lopeman, Harold E., Electronics Engineer for Illiac
McGinnis, Gerald A., Sr. Elec. Tech.
Meagher, R. E., Chief Engineer
Michael, George W., Administrative Assistant
Miller, Raymond E., 1/2 time Research Assistant
Muller, David E., Res. Asst. Prof. of Applied Math.
Nash, J. P., Res. Prof. of Applied Math.
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Ogata, Albert I., Student Assistant
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Pelg, Edmund, Jr. Electronics Tech.
Polivka, Raymond P., 1/2 time Research Assistant
Poppelbaum, W. J., Research Associate
Reynolds, Donald, Student Assistant
Robertson, James E., Res. Asst. Prof. of Elec. Eng.
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Seshu, Mrs. Lily, 1/2 time Research Assistant
Stephens, Allen, Jr. Laboratory Mechanic

Taub, A. H., Res. Prof. of Applied Math.
Wenta, Joseph, Sr. Electronics Technician
Wier, Joseph M., Research Associate (3/4 time)
Yii, Roland H.C., 1/2 time Research Assistant
Yu, Hwa-Nien, 1/2 time Research Assistant

The work of the group is under the administration of an Executive Committee with the following members: N. M. Newmark, chairman, D. E. Muller, J. E. Robertson, A. S. Douglas, J. P. Nash, A. H. Taub, and R. E. Meagher.

R. E. Meagher.
R. E. Meagher

REM/hc

UNIVERSITY OF ILLINOIS
GRADUATE COLLEGE
DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

Teaching and graduate research are
not, in general, reported herein.

January 1, 1955 - January 31, 1955

I. MATHEMATICAL RESEARCH AND PROGRAMMING. (This work is supported in part by ONR Task 30.)

Drum Use for Code Checking Routines

The influence of the magnetic drum upon checking routines has been studied. A reduction in the number of checking routines and an increase in versatility of checking methods is now possible. The following routines have either been prepared or are contemplated.

a) A general post mortem routine which requires only locations 0, 1 and 2 of the Williams memory. Printing may be in any of five forms: fractions, integers, order pairs, sexadecimal words, or floating point numbers.

b) A similar program for words located on the drum.

c) A comparison-type post mortem to replace the present library routine C1, the basic post mortem routine. The new version cannot be overwritten, will not cause double printing of interludes, and the program, after being compared and started, will behave identically the second time. Moreover, and this is a very important improvement, the new routine will not depend upon the Decimal Order Input (library routine X1) but can be used equally well with sexadecimal or other input routines. This facility is obtained by using an interpretive routine to read in the program being tested, reference being made to the drum whenever an order being tested refers to a part of the Williams memory occupied by the post mortem routine. When a stop transfer order is encountered, the program may be arranged to compare words in the original program (now placed on the drum) with words in the re-read program. No printing will occur if words agree of if words in the second reading are zero.

d) A sequence checking routine similar to the Scot program. This would use the drum only when that part of the Williams memory occupied by the master routine is infringed upon.

Combining the routines described in (a), (b) and (c) with library routine C6 (address search) and D1 (check point) we have about 250 words which, if held permanently on the drum, will give programmers a great variety of quickly accessible checking aids.

Drum Programs

Routines were written and checked during the month:

1) A sexadecimal drum input routine for transferring sexadecimal words from tape to specified drum storage locations.

2) An electrostatic memory input routine (for use with the drum bootstrap) whose function is to transfer sexadecimal words from specified drum locations to specified electrostatic memory locations.

3) A modified version of the leapfrog with automatic post mortem. The leapfrog was lengthened by six words to accomodate a drum bootstrap. The leapfrog bootstrap transfers an input routine from the drum to the electrostatic memory. The input routine then transfers a post mortem routine from the drum to the electrostatic memory. Both the input routine and the post mortem routine are placed in locations other than those assigned to the five leapfrog copies. The post mortem routine compares leapfrog copies 2 through 5 with the leapfrog copy on the drum, prints discrepancies, and corrects all electrostatic memory copies. After the post mortem, the leapfrog run can be continued, or the leapfrog can be crippled in place.

4) Using routine (1) above, the commonly used code checking routines have been recorded on the drum. Using routine (2) and a short specification tape, the desired routine can then be transferred from the drum, with a consequent reduction in tape handling and reading time.

Random Numbers

The generation of pseudo-random numbers by methods which do not involve multiplication (and which are thus faster) is being studied. One simple jumbling process involves permuting digits and adding. Chi-square tests will be made to test the results.

Floating Address Routine

An input program making use of floating address techniques is being written.

Differentiation

In response to a number of inquiries, consideration has been given to a differentiation routine. A general expression can be obtained for the nth derivative of Neville's interpolation formula. This formula is such that a simple cyclic process yields successive derivatives. Scaling may be handled by computing $f^{(n)}/h^n$, where h is the interval between tabulated points.

II. LIBRARY ROUTINES.

During the month of January, the following five programs were added to the active Illiac library. The ones marked "preliminary" will not be distributed until they have been used enough to see whether modifications are desirable.

L4 (166)	Half-Precision Solution of a Set of Simultameous Linear Algebraic Equations. 159 words. This is an open routine capable of handling 52 equations with at most 5-decimal accuracy. It forms the basis for automatic routine L5.
X9 (169)	Program Interruption Routine. 34 words. This routine is for use when an incomplete program must be removed from the computer and will be put back later.
X10 (170)	Program Interruption Routine with Sum Check. 49 words. Similar to X9, this routine contains a sum check for comparing the re-set program with the program existing just prior to its removal.
N7 (172)	Transfer Blocks of Words from Williams Memory to Drum or from Drum to Williams Memory. 43 words. PRELIMINARY. This is a closed routine using 3 parameters to designate the transfer of r words from locations beginning at n to

locations beginning at q. In going from the Williams memory to the drum, a sum check constant is recorded at location q+r. If the same constant is not obtained on playback, the machine stops. The time required is 10+3.3r milliseconds.

C9 (174) Print Sets of Floating Decimal Numbers and Their Decimal Locations. 36 words. This is a post mortem routine for use with floating point routine A1 and its associated programs.

III. MACHINE USE.

The following list gives problem specifications for new problems which were tried in January. It does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 481. Numbers followed by T are for thesis problems.

NUMBER	PROBLEM SPECIFICATION	AFFILIATION
481 T	Deuteron problem	Physics
482	Autocorrelation of syllables per word	Psychology
483	Heat conduction	Mech. Eng.
484	Correlation of corn ratings	Agronomy
485 T	Simultaneous linear equations	Civil Eng.
486 T	Pattern analysis of senatorial voting	Psychology
487 T	Tic tac toe learning program	Computer
488	Analysis of testing procedures	Education
489	Kinetics of consecutive reactions	Chemistry
490	Test for determinant routine	Computer
491 T	Proper moves table for tic tac toe	Computer
492	Least squares for ultracentrifuge data	Chemistry
493 T	Accumulation of correct tic tac toe plays	Computer
494	Inbreeding versus outcrossing	Dairy Science
495	Solution of polynomial equations	Economics

Table I shows distribution of machine time for January.

TABLE I

Regular Maintenance and Illiac Engineering (usually 8:00 A.M.-12:00 N)	58:50
Unscheduled maintenance or repair	23:16
Drum Engineering	23:39
R.A.R.	7:09
Leapfrog	82:11
Wasted	:59
Computer Use by Departments	
Computer Group	56:16
Classes	11:24
Demonstrations	1:16
Physics	31:54
C.S.L.	65:18
Struct. Res.	16:10
Struct. Res. (AF24994)	7:59
Struct. Res. (Nobs62250)	27:35
Psychology	15:14
Psychology (AF25726A)	1:30
Elec. Eng.	17:48
Chemistry	26:39
Agriculture	20:05
Cosmotron	20:40
Indiana University	4:43
Chanute Air Force Base	3:56
Miscellaneous	19:09
Total	543:39

IV. ERROR FREQUENCY AND ANALYSIS.

The machine is normally used for "engineering" and maintenance between 8:00 A.M. and 12:00 N, and for a check of its performance between 5:00 and 5:30 P.M. of each weekday. Since the periods between 8:00 A.M. and noon, together with certain irregular periods like Saturdays and Sundays, are devoted to a heterogenous group of functions, it is more instructive from an error analysis standpoint to look at the periods between noon and 8:00 A.M. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind, a summary table has been prepared using the period between noon and 8:00 A.M. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 5:00-5:30 P.M. period (when the machine is checked) if no errors are found, the time is given to the "running column." Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leap-frog code is our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that any interruption of machine time that was not planned for is considered a failure in this table. In rare cases where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This overall system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" at any instant of time and the probability of a failure during any given interval of running time.

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
1/3/55	20:00	:00	0	Reader failed because of dirt in light bulb.	:00	1:38	0
1/4/55	19:52	:08	5	(1) Reduced light for sprocket hole. (2) Division hang-up neon shorted. (3) Known error in result. (4) Reader "E" reading same character twice. (5) Reader "C" drive roller did not release.	:00	2:18	1
1/5/55	19:53	:03	3	(1) Leapfrog error. Arithmetic error. (2) Punch failure because chad chute was clogged. (3) Punch failure because chad chute was clogged.	:04	2:15	1
1/6/55	19:59	:01	1	(1) Leapfrog arithmetic failure.	:00	4:39	1
1/7/55	18:19	1:41	2	(1) Although supposed to be stopped on a 24 order the machine went on without using black switch. (2) Cathode to filament short in V24 (6J6) in shift counter.	:00	3:01	0
1/10/55	19:20	:36	1	(1) Reader trouble.	:04	2:20	0
1/11/55	19:56	:01	1	(1) Tape cut under brake of reader causing an error.	:03	2:29	0
1/12/55	18:51	1:08	4	(1) Hung up on K5 00F from 080. 2nd time OK. (2) Reader "E" failed. (3) Reader "C" cut two tapes. (4) Leapfrog input-output failure.	:01	3:16	1
1/13/55	19:59	:01	1	(1) Reader "E" cut tape.	:00	2:30	0
1/14/55	19:50	:00	0		:10	2:49	0
1/17/55	19:40	:20	2	(1) 1→0 failure pos. 11 of memory. (2) Output indicated probably that a number had been read in incorrectly.	:00	2:34	1

DATE	RUNNING OK TIME	REPAIR TIME	TIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
1/18/55	18:01	1:54	5	(1) Stopped on a 10 020 from 126. (2) Hung up in 74003. Lowered 100v power supply temporarily and continued. (3) Green gate tolerances caused hang-ups on L and F orders. (4) Hung up on 11 020 from ON6. (5) Improper division hang-up neon did not light.	:05	3:08	0
1/19/55	17:26	2:34	2	(1) Hang-up when trying to read in. (2) Stopped on 10020 three times.	:00	2:56	0
1/20/55	19:50	:08	2	(1) Run-over from morning engineering. (2) Hung up on 11020 from ON6.	:02	2:46	0
1/21/55	19:55	:05	4	(1) Reader "C" tore tape. (2) Reader "C" reading erratically. (3) Hung up on 11020 from ON6. (4) Punch jammed.	:00	2:29	0
1/24/55	20:00	:00	0		:00	2:09	0
1/25/55	19:59	:01	1	(1) Reader "C" would not pull tape.	:00	2:37	0
1/26/55	19:30	:30	1	(1) Leapfrog 2^{-38} 0→1 memory error. Grid-cathode short in 2C51.	:00	2:46	1
1/27/55	19:58	:02	1	(1) Leapfrog input-output failure.	:00	2:38	1
1/28/55	11:43	8:17	4	(1) Reader "E" tore tape. (2) Error in dividing -2^{-39} by $4x2^{-39}$ because of peculiar tube short in carry delay chassis. (3) Reader "C" tearing tapes. (4) Delay chassis tubes producing errors.	:00	1:03	0
1/31/55	19:56	:01	4	(1) Reader skipped two zeros. (2) Believed error in read-in. (3) Read-in error from dirt in one hole (4) Unknown error in CSL program.	:00	2:26	0
TOTAL	401:57	17:37	44		:29	54:47	7

V. COMMENTS ON THE ILLIAC AND RELATED FACILITIES.

During the year 1954, the Illiac was operated 5251 hours and during this time a total of 1929 tubes were changed. Out of the total number of tubes changed, 150 tubes were replaced because of tube failures which produced errors or interruptions of Illiac running time. 102 of these tubes were changed during the operating period of the machine between noon and 8:00 A.M. the next morning.

The new 60-character per second punches are being tried with the Illiac. Difficulties have been encountered using the contacts supplied with the punches for "A" and "B" gates. The contacts do not remain 180° open, 180° closed, when the contact positions are changed. Errors in punching occur when starting and stopping. This is caused by the feed magnet not starting soon enough so that two characters may be punched over one another and stopping too late so that a zero is punched at the end of a string of characters.

The photoelectric tape comparer is being checked with minor changes in the logic and circuitry being made. The unit is operating most of the time but occasionally the two readers get out of step. This trouble is now being checked.

VI. RESEARCH ON COMPUTER COMPONENTS. (This work is supported in part by ONR Contract N6ori-07124.)

Magnetic Core Study

While experimenting with magnetic cores, a method of sensing certain magnetic cores was found which does not disturb the information in the cores. It was found that it is fairly simple to read out of steel cores nondestructively by using a pair of very short sensing pulses. These cause the core to be moved around a reversible loop about the remanent point. Thus if the core is residing at one remanent point and two short pulses of sufficient amplitude to turn the core over but of insufficient duration are applied,

one of each polarity, the signal out on any pickup winding resulting from the flux change gives a method of reading the contents without destroying them. Thus if we look at the output during the first of these two pulses, we should expect to see a relatively large signal if the core is driven toward a knee and a small one if it is driven away from a knee. Further, since the direction of the knee from the remanent point is dependent upon which of the remanent points acted as the starting point for this operation, the output signal is a measure of the remanent state. Thus if a core is set to the negative remanent point and a pair of short sensing pulses, the positive one coming first, are sent through the core, then a large signal will appear at the advent of the first pulse, while if the core had started at the positive remanent point, the large pulse would not have occurred until the second sensing pulse. It was found that Deltamax cores operate very well in this fashion and enable one to read out of such a core in something like a microsecond, which is much faster than by any other means, using reasonable amounts of driving power. Permalloy cores also allow such reading although the sensing discrimination was not so good. All attempts to do such reading from ferrite cores failed. It is felt that these results are caused by the relative squareness of the hysteresis loops of the various materials. Since the selected signal must come from passing slightly over the knee and since the unselected signal comes from moving along the saturated portion of the hysteresis curve, the selection ratio, that is the ratio of the sizes of the two types of output signals, is best when the motion over the knee is great or when the slope of the saturation portion is very small. Since we are restricted in the amount by which we can pass the knee, it is necessary that the other slope be fairly small so as to have small unselected signals. It is felt that the Deltamax is best in this respect and the ferrites are worst, the latter being bad enough so that the unselected signal is nearly as large as the selected one for any stable loop about a remanent point.

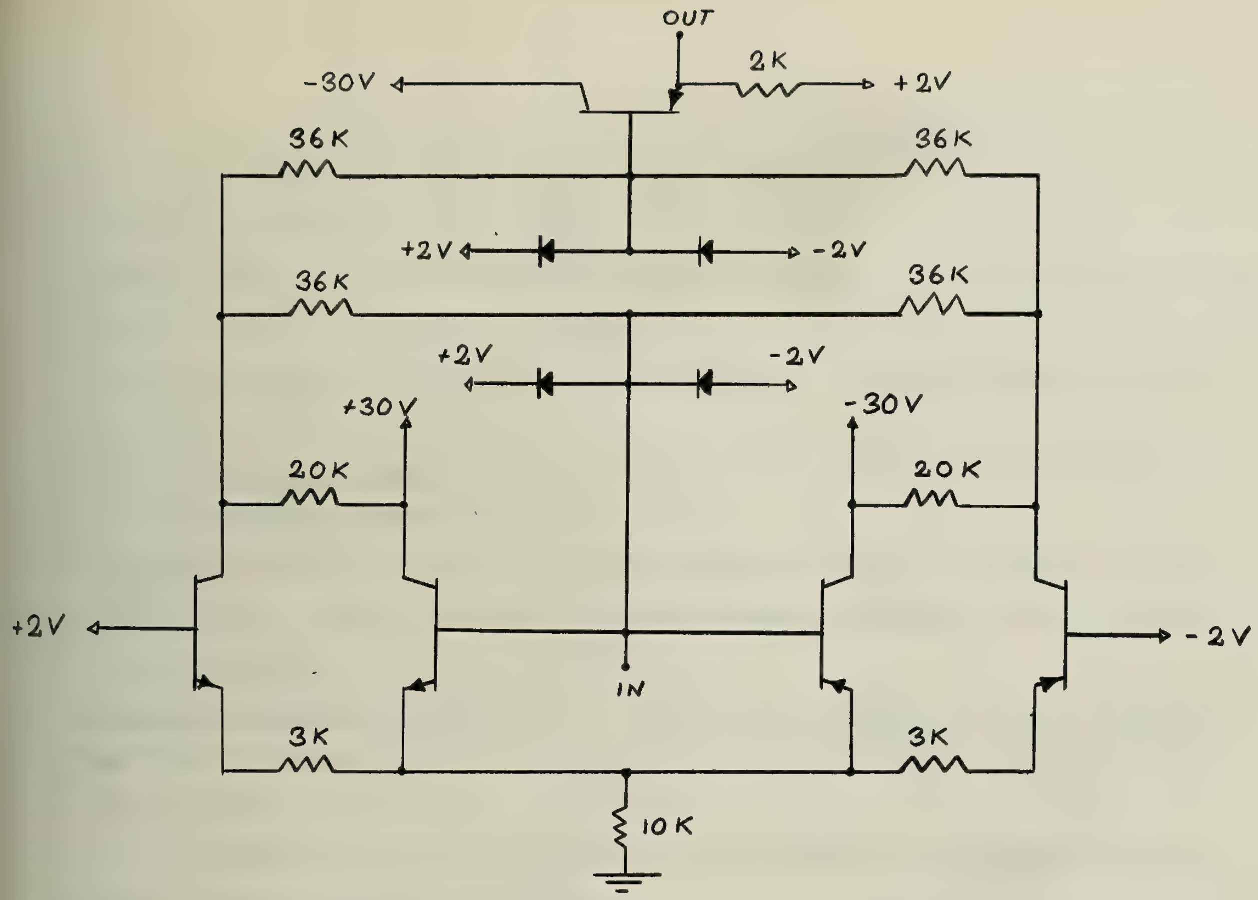
A method of passing pulses through a magnetic switch in which pulses are larger in amplitude in one direction than in the other was also devised, along with a method of controlling independently the amplitudes of these pulses. Such a pulse system was deemed desirable for use in a magnetic core storage system. By making a memory organized on a word selection basis, it is possible to greatly overdrive the cores on reading, since no switching property of the storage cores is used during reading. Thus if the first of two pulses has a large current amplitude the storage cores will flip over very rapidly and a very short readout time will result. Then, when it is necessary to put this information back into the cores, a pulse of lesser current amplitude and longer duration may be used, the time integral of the output voltage, of course, being zero.

Using the above switch, it seems possible to devise a magnetic core memory in which only three wires pass through each core. Such a matrix may be driven in one dimension by a magnetic matrix switch and by hard tube drivers in the other. A 600-core storage matrix is being wound currently to test this hypothesis and to get a better measure of the amount of work necessary to do the actual winding.

Direct-Coupled Transistor Circuits

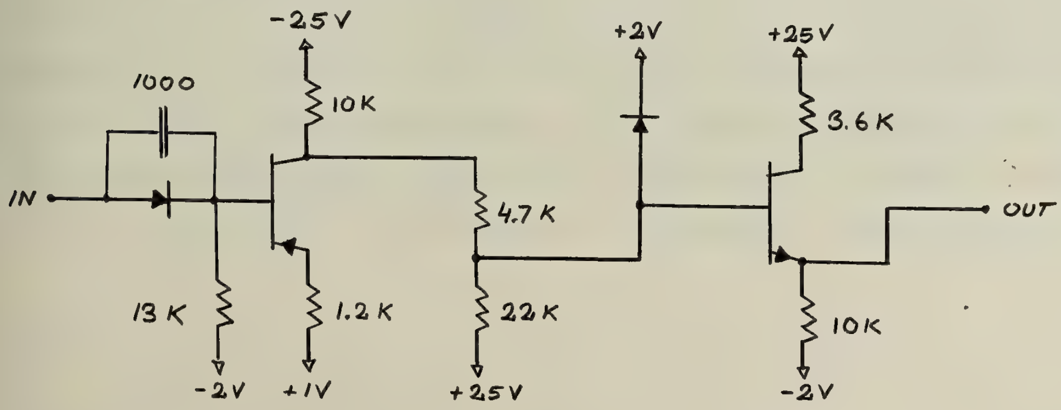
The four bit double shifting register was built and tried out in manual operation. The experiments with pulse operation will be resumed as soon as low-capacity miniature diodes are available for the gating circuits.

The npn-pnp flipflop circuit was slightly modified for control applications in which a last moving point output is needed. It is thus necessary to connect a second voltage divider across the collectors of the dc amplifier and to take the mid-point as the output: The high output impedance encountered forces us then to go out through an emitter-follower. It turned out that with the values indicated in the figure the overall rise and trail-off time of the circuit is still of the order of one microsecond.



Flipflop with "last moving point" output.

Efforts were made to simplify the proposed building blocks, i.e. to reduce the number of transistors in a given circuit. In particular a not circuit was designed which only uses two instead of four transistors. The price we have to pay for this simplification is: a lower input impedance (10KΩ instead of 20KΩ), a longer rise-time and trail-off-time (1.5 μs instead of 1 μs), a less favorable ratio of minimum to maximum signal at the input (1:2 instead of 0.6:2) and lastly the use of a speed-up capacitor across the input. A further drawback is the higher cost of the high-α output transistor.



A Not Circuit using Two High-α Transistors

It is hoped that in the near future design rules can be laid down for the transistorized building blocks. It is proposed to adopt the following standards:

Signal Levels: "0" corresponds to signal between -2V and -1V; "1" corresponds to signals between +1V and +2V.

Rise-Times, Trail-Off-Times, Turn-over-Times: All these times should be less than 1.5 μs.

Input and Output Impedances: All input impedances should be $\geq 10K\Omega$ and the minimum load should be as low as $2K\Omega$.

Tolerances: All voltages, transistor parameters and resistance values should at all times be within 5% of the nominal value, except i_{co} which shall be 10 μA ± 100 μA.

Collector and Bias Voltages: All collector voltages should be ± 25V and the bias voltages used should be ± 1V or ± 2V. The only exceptions are the read-out circuits.

A technical report giving the calculations for the npn-pnp flip-flop in detail has been prepared.

Magnetic Drum Auxiliary Memory

During the month of January, the 2048-word experimental drum storage unit was made available for code checking and production runs. The following decisions conerning design of the final unit were made on the basis of operating experience with the experimental unit:

1) Calculation time between successive words: Initially, leads between the drum word counter and the drum coincidence circuits were permuted in such a way that successive Illiac addresses usually coincided with every fourth state of the word counter. Since there is an enforced delay of two words, and since the transfer of information between the drum unit and the Illiac requires one word time, one word time (approximately 527 μs) remained for Illiac calculation between successive drum consultations. This calculation time is deemed insufficient, and a minimum of three word times at double the density (780 μs) is proposed for the final unit. During the month of January, the drum word counter

was rewired to count by 13's, with the result that the state of the word counter increases by a unit each time five words are counted. From the Illiac viewpoint, successive addresses coincide with every fifth drum word, and the time available for calculation is two drum word times, or 1.05 µs. Two and one-half additional tubes were required for this change.

2) Maintenance experience during the month indicates that a faulty preamplifier switch tube is difficult to isolate, since fifty switch tube cathodes are in parallel. It is proposed that the preamplifier chassis for the final drum unit be rewired for the 2C51 double triode, which is more reliable than the 6BQ7 type now in use. Difficulty was also encountered with the pulsers in the drum unit. It was found that the triggering of the pulsers is a critical function of both the input waveform and of the individual 6AK5's within the pulsers. Further investigation of the triggering arrangements is required.

3) Location of preamplifier output busses: It was found that signals on a preamplifier output bus connected to an unselected playback amplifier were coupled to the input of the selected preamplifier, due to the physical location of the output busses. All output busses have been removed. A significant increase in the gain tolerance ratio--from 1.2 to 1.75--was noted as a result of this wiring rearrangement.

VII. CONSTRUCTION.

Additional parts of six photoelectric tape readers have been made.

A test setup of the photoelectric tape comparer was completed and checked out. Several wiring errors and several diagram errors were found. Also several changes in the logic and the wiring were made. The unit still makes occasional errors so no test run for error-free time has not been made. It was found that two Variacs were necessary due to the difference in the operating voltages of each reader.

A drum head test circuit, Dwg. L614, was constructed and partly wired for the drum group.

Other work in the shop was as follows: A 815-tube checker was constructed, wired, and checked out. 800 6J6 and 400 5687's were checked both electrically and mechanically. A 5-tube test chassis for the transistor group was constructed and wired. A power distribution panel was contructed and wired for the transistor laboratory.

VIII. REPORTS AND SEMINARS.

Reports

"A Fast Junction Transistor Flipflop with Stabilized Output Levels" by Wolfgang Poppelbaum, January 24, 1955.

Seminars

"Random Numbers and Monte Carlo Methods," J. P. Nash, January 5, 1955.

"Use of Monte Carlo Techniques with Illiac to Test a Model Describing Human Behavior," Leroy Augenstine, January 12, 1955.

"Programming for the Illiac Drum Memory," James E. Robertson, January 19, 1955.

IX. PERSONNEL.

The personnel associated with the group and hence the contributors to this report are:

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Breed, Charles P., Draftsman
Carter, Clifford E., Electronics Engineer for Illiac
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Farrington, Carl D., 1/2 time Research Assistant
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Fishel, Jerome, 1/2 time Research Assistant
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Michael, George W., Administrative Assistant
Miller, Raymond E., 1/2 time Research Assistant
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Nash, J. P., Res. Prof. of Applied Math.
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The work of the group is under the administration of an Executive Committee with the following members: N. M. Newmark, Chairman, D. E. Muller, J. E. Robertson, A. S. Douglas, J. P. Nash, A. H. Taub, and R. E. Meagher.

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UNIVERSITY OF ILLINOIS
GRADUATE COLLEGE
DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

Teaching and graduate research are
not, in general, reporter herein.

February 1, 1955 - February 28, 1955

I. MATHEMATICAL RESEARCH AND PROGRAMMING. (This work is supported in part by ONR Task 30.)

Boolean Algebra

A method of handling part of the synthesis switching circuits using implicit Boolean functions has been discovered. This treatment has the following advantages:

a) Transformations of the system which preserve sequencing properties may be regarded as mathematical transformations of a single Boolean function which completely describes the sequencing properties of the circuit.

b) A circuit having the desired properties may be obtained from this single function by carrying out certain systematic manipulations.

c) Use of this function allows one to correct time difficulties (race conditions) which may exist in a reduced circuit provided these difficulties are of a particular type.

An internal report will be prepared describing this material in more detail.

Order Analysis

A program was written to count order types as they are obeyed in an arbitrary program. This program also counts the total number of shifts of each type and the total number of characters input and the total number of characters output. Several different library programs have been studied this way. Results indicate that in the fast loops of programs the arithmetic requires from two to three times as much time as the red tape operations.

Simultaneous Equations

There has been checked a linear algebraic equation solver which, with present magnetic drum capacity of 2048 words, is limited to 72 equations. The elimination method is used and the drum is referred to only when necessary. That is, if there are 37 equations or fewer, the drum is not used at all. This technique speeds up solutions considerably. The time required for 64 equations is about 15 minutes.

A routine for finding inverses and solving several sets of linear equations simultaneously is being prepared and will undoubtedly supersede other equation solvers for certain classes of problems in which only the column vector of constants is changed.

Numerical Differentiation

Neville's interpolation formula

$$f_{(x_1x_2\ldots x_k)}(X) = \frac{(X_k - X)\, f_{(x_1x_2\ldots x_{k-1})}(X) - (X_1 - X)\, f_{(x_2x_3\ldots x_k)}(X)}{(X_k - X_1)}$$

can be used to calculate the n^{th} derivative when $f(x)$ is defined over the equally spaced points $x_1, x_2, \ldots, x_k$. A program for calculating $f^{(n)}(x)$ will serve two purposes: interpolation and differentiation. The interpolation is being done essentially as in Library Routine I1 (67). The interpolation formula is not being scaled since it is reasonable to assume that the function is well-behaved and that the interpolate will be within range if the values at neighboring points are within range.

Random Numbers

A set of interconnecting programs was written for running chi-square frequency tests on different types of routines for generating pseudo-random numbers. Several schemes for generating such numbers have been tested, and results are now being interpreted.

Floating Address Routine

This drum program, a modification of the Decimal Order Input (Library Routine X1) will recognize bracketed symbols (floating addresses) to be used with reference to words appearing sooner or later in a given program. It is being prepared in several parts: (I) recognition of a floating address, (II) formation of a list, (III) identification of words with floating addresses, (IV) replacement of floating addresses, (V) transfer of proper drum section to Williams memory, (VI) coordination with Decimal Order Input.

II. ANALYTICAL PROGRAM. (This work is supported in part by NSF Grant G-1221.)

Boundary Value Ordinary Differential Equations

The Sturm-Liouville differential equations are typical of a large class of boundary value problems in ordinary differential equations. These equations are the Euler equations of a problem in the calculus of variations. This suggests that approximate solutions and approximate proper values corresponding to these solutions may be obtained by approximating the calculus of variation problems and then minimizing the resulting quadratic form. Work is in progress toward the determination of the relation between this method of approximating the Sturm-Liouville differential equations and the more usual method of replacing the differential equation by a finite difference equation. It was shown earlier that the two methods were equivalent in the first order approximation case. The situation in the second and higher order approximation cases is now being examined.

Relativistic Hydrodynamics

The Einstein field equations for the gravitational field and the hydrodynamic field variables of a perfect gas in the case where plane or spherical symmetry attains have been studied. Special solutions have been found. Methods for dealing with non-isotropic flow as well as isotropic flow were found. The equations are being studied with a view of formulating them for machine solution.

Shock Waves

Problems in stationary and pseudo-stationary flow with shock waves present have been reduced to Cauchy problems with the shock as the curve on which the initial data is assumed given. The stability of these Cauchy problems and the relation between the shock curve and other curves in the flow is being studied.

III. LIBRARY ROUTINES.

During February the following three programs were added to the active Illiac library:

M 12 (173)	Matrix Triangularization and Computation of Its Determinant. Complete Program. Given any number of properly scaled square matrices of order up to 40 this program will successively upper triangularize and compute the determinant of each.
C 10 (175)	Combined Post Mortem. 80 words. Using the drum (so that only words 0, 1, and 2 of the original program are overwritten) this checking routine will print selected sets of 10 consecutive owrds in a manner chosen by the user. Words may be printed as fractions, integers, order pairs, floating point numbers, or sexadecimal words.
C 11 (176)	Drum Order Pair Post Mortem. 35 words. This routine takes words from 10 consecutive locations on the magnetic drum and prints them as order pairs.

IV. MACHINE USE.

During February 20 new problem specifications were presented, and they are given below. This list does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 496. Numbers followed by T are for thesis problems.

496 T	Economics. Effects of price change, retirement, and advertising. The polynomial equation solved is derived from a model of the national economy.
497	Education. Calculation of validity coefficients of multiple choice items. Parameters used are probabilities of response to a multiple choice item for three criterion groups.

498 Chemistry. Computation of Patterson function. It is required to compute the double sum

$$\sum_{h=-12}^{12} \sum_{\ell=0}^{32} F^2(h,\ell) \cos 2\pi \left(\frac{hx}{a} + \frac{ky}{b} \right)$$

499 Mechanical Engineering. Reduction of regenerative gas turbine test data to basic parameters.

500 Computer. Chi-square test for random numbers. The program tests routines designed for generating pseudo-random numbers by calculating chi-square for batches of sexadecimal characters.

501 Agricultural Economics. Multiple Correlation. The least squares method is used to compute sums, zero order matrix, inverse matrix, standardized regression coefficients and regression coefficients using up to 12 variables.

502 Psychology. Estimation of rank of a matrix. Three small matrices will be used to investigate a new suggestion for estimating the psychological rank of a correlation matrix, i.e., the number of "common" factors which can be extracted from a matrix.

503 T Education. An analysis of the internal structure of the Differential Language Facility Test. The problem is to obtain a 14 variable correlation matrix.

504 Psychology. Second order factorization of motivation factors. The program plots some 30 axes in graphs, calculates the inverse of a 15 by 15 matrix and carries out a principal components factorization of the resultant matrix.

505 Psychology. Factor analysis of meaning. The problem is aimed at finding the factors in semantic space which define meaning. The variables are 76 word pairs which are opposite in meaning (e.g., "good-bad"). The sample size is 2000.

506 T Psychology, Purdue University. Logical fallacies. The problem involves the principal axes solution of a 40-variable correlation matrix.

507 Theoretical and Applied Mechanics. Stresses in conical shells. Stress solutions are found by expressing second order Kelvin functions in terms of products of exponential functions, trigonometric functions and rapidly converging series.

508 Physics. Particle motion. The problem is to solve the pair of simultaneous differential equations which describes the motion of a particle in a synchrotron which has ridged magnets to form an alternating gradient.

509 Psychology. Factor analysis. A 23 by 23 matrix has elements which are intercorrelations of structural elements of expression in reading material (such as number of polysyllables, number of first person pronouns, etc.). Analysis may reduce the 23 variables to a smaller number and aid design and execution of experiments to determine their influence in reading difficulty.

510 Agronomy. Split plot analysis of variance. The program will be used on agricultural yield data.

511 State Water Survey. Variation of rainfall with distance. The problem is to use statistical techniques to determine an empirical regression equation which can be used to predict or estimate the standard error in rainfall estimates at various distances from a fixed rain gauge location.

512 Mechanical Engineering. Predicting hardenability of steel from its chemical contents. The statistical routines of the program library are used to obtain regression weights, standard error, and multiple correlation.

513 Psychology. Aptitude of mechanics. The problem is to perform factor analysis upon aptitude, morale and job-knowledge tests given to 500 aircraft mechanics.

514 Computer. Analysis of order types. An interpretive routine counts the number of times each order type is obeyed in an arbitrary program.

515 Computer. Matrix inversion. This is a test for a new matrix inversion routine.

Table I shows distribution of machine time for February.

TABLE I

Regular Maintenance and Illiac Engineering (usually 8:00 A.M. - 12:00 N)	48:38
Unscheduled Maintenance or Repair	14:28
Drum Engineering	27:44
R.A.R.	5:54
Leapfrog	47:47
Wasted	:51
Computer Use by Departments	
Computer Group	27:05
Physics	16:15
C.S.L.	51:38
Struct. Res.	8:35
Struct. Res. (AF 24994)	21:24
Struct. Res. (Nobs 62250)	117:49
Psychology	2:41
Psychology (AF 25726 A)	8:07
Electrical Eng.	22:19
Chemistry	39:08
Agriculture	13:02
Cosmotron	11:09
Indiana University	:55
Purdue University	:25
Harvard University	:09
Miscellaneous	16:47
Demonstrations	1:30
Total	504:20

V. ERROR FREQUENCY AND ANALYSIS.

The machine is normally used for "engineering" and maintenance between 8:00 A.M. and 12:00 N, and for a check of its performance between 5:00 and 5:30 P.M. of each weekday. Since the periods between 8:00 A.M. and noon, together with certain irregular periods like Saturdays and Sundays, are devoted to a heterogenous group of functions, it is more instructive from an error analysis standpoint to look at the periods between noon and 8:00 A.M. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind, a summary table has been prepared using the period between noon and 8:00 A.M. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 5:00-5:30 P.M. period (when the machine is checked) if no errors are found, the time is given to the "running column." Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that any interruption of machine time that was not planned for is considered a failure in this table. In rare cases where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This overall system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" at any instant of time and the probability of a failure during any given interval of running time.

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
2/1/55	14:12	5:48	6	(1) Reader "E" error. (2) Memory error. 2^{-38} (3) Memory error. 2^{-13} (4) Two different results from same tapes. (5) Leapfrog comparison failure. (6) Leapfrog multiplication failure.	:00	1:13	2
2/2/55	19:55	:03	3	(1) Tension on tape produced error in reader. (2) Possible reader error. (3) Leapfrog. Reader skipped a character.	:02	2:48	1
2/3/55	19:35	:19	4	(1) Reader "E" does not pull tape. (2) Reader "C" does not pull tape. (3) Leapfrog multiplication failure. (4) Leapfrog type not listed.	:06	2:35	2
2/4/55	12:06	:01	1	(1) Leapfrog. Reader "E" failed to read a "two" hole.	:00	:24	1
2/7/55	20:00	:00	0		:00	3:06	0
2/8/55	19:52	:02	1	(1) Reader "E" tore tape (brake and clutch on at same time).	:06	2:43	0
2/9/55	19:54	:00	0		:06	2:52	0
2/10/55	19:57	:00	0		:03	2:34	0
2/11/55	19:57	:03	3	(1) Reader "C" broke tape in two pieces. (2) Reader "C" reading erratically. (3) Two different results from same tapes.	:00	:34	0
2/14/55	15:37	4:23	3	(1) Leapfrog memory error. $0 \rightarrow 1$ 2^{-37} (2) Leapfrog failed. Trouble in address generator (3) Two different results from same tape.	:00	1:34	1
2/15/55	20:00	:00	0		:00	1:32	0
2/16/55	20:00	:00	0		:00	1:05	0
2/17/55	19:53	:07	1	(1) Probably $0 \rightarrow 1$ in 2^{-3} in memory, R_3 or decoding chassis	:00	1:06	1

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
2/18/55	19:42	:18	5	(1) Reader "C" sprocket hole filled with lint causing an error. (2) Two different results from same tapes. (3) Two different results from same tapes. (4) Two different results from same tapes. (5) Punch ran out of tape, while problem was on.	:00	:53	0
2/21/55	19:59	:01	1	(1) Two different results from same tapes.	:00	1:21	0
2/22/55	20:00	:00	0		:00	1:10	0
2/23/55	19:02	:58	2	(1) Reader "C" failure perhaps because of dirt in holes. (2) Two different results from same tapes.	:00	1:39	1
2/24/55	18:11	1:49	2	(1) Two different results with same tapes. (2) Memory error $o \rightarrow 1$ 2^{-33}	:00	:52	0
2/25/55	19:53	:07	1	(1) Unknown.	:00	1:13	0
2/28/55	19:59	:01	1	(1) Leapfrog input-output failure using reader "C"	:00	:59	1
	377:44	14:00	34		:23	30:41	10

VI. COMMENTS ON THE ILLIAC AND RELATED FACILITIES.

The drum unit using the present drum and a capacity of 2048 words has been operating most of the time with the Illiac. It was necessary to check tubes in the drum unit and 209 tubes were changed during the checking period. This is the first time tubes have been checked in the drum for some time.

The photoelectric tape comparer unit has been made to operate satisfactorily and arrangements are being made to put it in the Teletype Room. A report concerning its operation has been prepared and should be read by each user.

Work has continued to make the 60-character per second Teletype punch operate from the present Illiac circuits. The punch has not yet operated satisfactorily because the punch magnets and the feed magnet require operation and release times which cannot be provided for both types of magnets at the same time.

The set of Teletype parts to modify a transmitter-distributor for 10 characters per second was received late in February. This set of parts is now being assembled and installed in a new transmitter-distributor. This transmitter-distributor will be used with the new Model 28 printer. Other maintenance and repair work on the tape preparation equipment included considerable overhaul and adjustment of the tape comparers. A relay circuit has been installed on one transmitter-distributor to allow reading of the tape one character at a time. This is now being used and tested on a reperforator reader combination.

VII. RESEARCH ON COMPUTER COMPONENTS. (This work is supported in part by ONR Contract N6ori-07124.)

High-Speed Vacuum Tube Circuits

A study has been started of vacuum tube computer circuits with operation times of about 10^{-8} seconds. Some comments about similar high-speed circuits were obtained from Mr. Grisamore of George Washington University

where an ONR contract has supported high-speed work suggested by J. von Neumann. A tube with an electron multiplier electrode has some desirable characteristics and one made by Philips with the type number EFP60 is an example. This tube is of the pentode type with a secondary emission electrode placed between the suppressor and the plate. This electrode is used as an electron multiplier to obtain a large transconductance without a corresponding increase in tube output capacity. A number of test circuits were built using this tube. A bistable circuit can be made by connecting the anode to some suitable positive voltage, the screen grid to about 150 volts, the suppressor to the cathode, the control grid to ground, the cathode to ground through a biasing resistor, and the secondary emission to ground through a resistor. This circuit exhibits two stable states, one with the dynode at cathode potential and one with it near anode potential. When the dynode is near cathode potential, the secondary emission ratio is below one and the dynode charges negatively toward cathode potential. If the dynode is at a potential high with respect to the cathode by a sufficient amount (greater than about 25 volts) the secondary emission ratio is greater than one and the dynode charges positively to the neighborhood of the anode. Such a flipflop is very stable with respect to wide variations in all of the electrodes and will even operate with a low resistance short between any pair of elements excluding the dynode. Since it has but one moving point, its operation is very fast since once that point is moved to the neighborhood of one of the stable states, the gating operation is complete, no series charging chain being present as with the Eccles-Jordan circuit. It suffers from the disadvantage that it requires a more or less special tube and that there is no complementary output.

While operating this tube, it was decided that it should be possible to utilize the secondary emission properties of the anode of a pentode or tetrode to achieve the same effect. A 6AU6 was wired to be used in this way with the grid and cathode grounded, the screen and suppressor tied to +150 volts and the plate tied to ground through a 100K ohm resistor. This circuit operates as predicted with the plate having the two stable states, one near the 150-volt suppressor voltage and one at cathode potential. It was found, however, that since the various tube manufacturers try to suppress

secondary emission from the plate, this element does not have a secondary emission ratio much above one in any voltage range tried, although some manufacturers are more successful in suppressing this quantity. With a sufficiently large plate resistor, however, all tubes tried would operate with two stable states. Unfortunately this circuit mistreats the screen and suppressor electrodes since a large amount of current must flow to these elements to get enough current to the plate to operate the tube with a reasonably low value of plate resistance.

As a point of interest, two flipflops of this general class were built in one double triode bottle by using the plates as secondary emitters and the grids as collectors, operating at +150 volts. The filament voltage was reduced to limit the currents. This circuit operated, but it was very sensitive to the filament voltage since the tubes were operated with the cathode currents temperature limited.

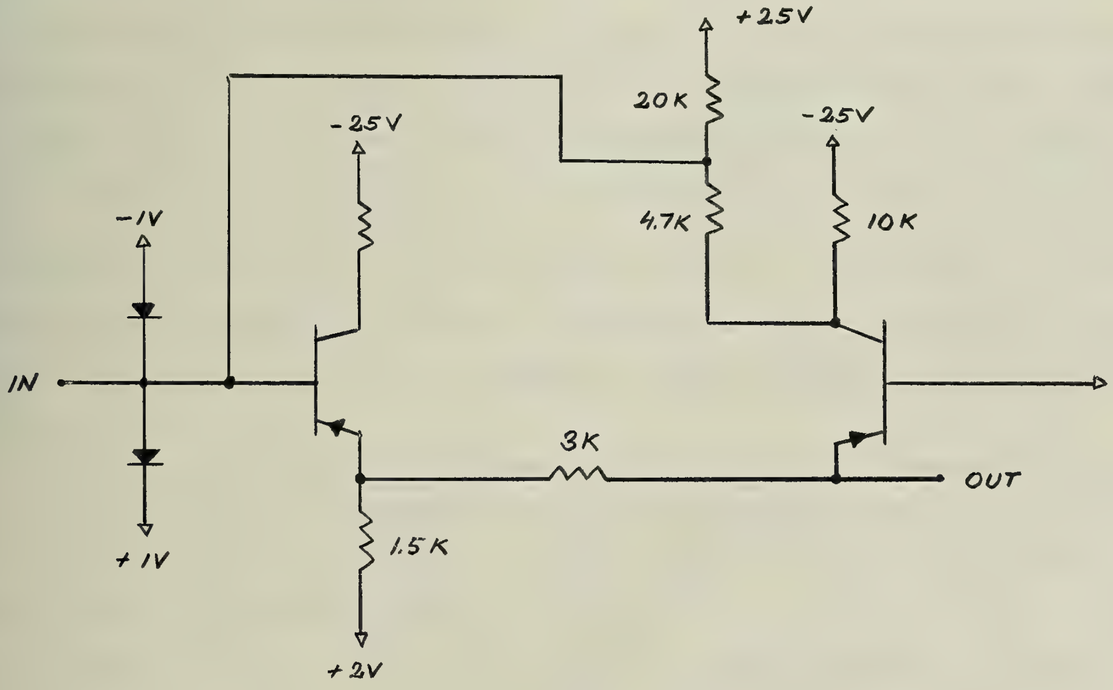
The various circuits were tested for turnover speed by rather crude methods. It was found possible to turn the EFP60 flipflop over by pulling up on the dynode with a pulse no longer than 50 millimicroseconds. It could also be set in the opposite direction in the same time by pulling down on the control grid. These were not the lower limits of operation time but were merely the points at which the pulse equipment used ceased to generate shorter pulses. The 6AU6 flipflop was set to the positive state by using a manually operated switch-capacitor discharge pulse generator. This circuit was calculated to produce pulses not longer than 10 millimicroseconds. These reliably operated the flipflop through a gate tube. No gate was built for setting the flipflop to the negative state although pulling down in a similar manner should do the job. The EFP60 tube flipflop was not tried with this gate, although it seems fairly obvious that it also could be gated in the same way at the same speeds.

Direct-Coupled Transistor Circuits

The main concern of the transistor group during the month has been the 4-bit double shifting register. When first tried the shifting register was not reliable because of noise from power lines. After putting RF filters into the power supply and using a certain amount of shielding very satisfactory results were obtained. In particular a 140-hour error-free run was made, the

gates being open for 10 microseconds and the dead time being of the same order. In practice gating times of 3 microseconds did not seem to cause any particular trouble even when the relatively slow diodes HD 2061 were used in the gates.

In the line of the simplification program started last month, a two-transistor flipflop has been developed. This flipflop is essentially a radical simplification of the original npn-pnp circuit. It has many of its advantages (high input impedance, low output impedance, a turnover time of the order of 1 microsecond), but it has not the self-balancing properties of the four transistor design. Furthermore the tolerances are much smaller.



A Two-Transistor Flipflop

VIII. CONSTRUCTION.

The status of the 6 new readers is as follows: All 98 parts for each reader have been started and all but 3 of these have been completed. The brake shoe guide and the tape guide are in process now. They have been finished up to the milling of the Tee slot. Some of the readers should be assembled and wired in the following month. It has been decided to change the method of mounting the

drive arm coils, to allow the adjusting of them to be made from the outside of the reader. This change can be made anytime so it will not hold up the completion of the readers.

Time has been spent on trying to find the cause of errors in the present readers.

Changes were made in the circuits of the photoelectric tape comparer units. A temporary cover will be installed on the unit and it will be set up in the Teletype Room for trial and comments before the final unit will be made up.

The record amplifier CF chassis for the final drum unit, Dwg. M 594, has been completed and wired, and is now ready for checking. A new word counter has also been built for the final drum unit, and the wiring is nearly completed. It is a 1/2 bay 8 gang chassis. This will take the place of 1/2 bay 6 gang bay chassis and 2 1/2 bay 1 gang chassis now used. This is to cut down on the vertical height the word counter uses in the final unit. The drum head tester, Dwg. M 614, was completed and a plug was installed in the drum test unit for the head tester power and signal supply; a 5-tube experimental chassis was also built and wired for the drum group.

A battery charger panel was constructed and wired for transistor group work. A transistor parameter tester chassis was constructed and wired. A small 3-tube experimental chassis was built and wired. A 3'x1-1/2'x1-1/2' screen-wired shield wood-frame box was constructed.

The main design of the final drum unit has been completed. There are three drawings available which give all the main and general details of the unit, with and without covers, such as the overall dimensions, location of all circuits, and large components. The items left to be designed include small things such as air panel, lock open hinges, two door hinges, some small mounting brackets, etc.. Several detailed drawings for about twenty different parts have been finished.

IX. REPORTS AND SEMINARS.

Seminars

"Basic Principles of Junction Transistors and Fast DC-Coupled Computer Circuits Using Junction Transistors"
by W. J. Poppelbaum, February 2, 1955.

"Fast DC-Coupled Junction Transistor Circuits"
by W. J. Poppelbaum, February 9, 1955.

"Processing Statistical Data by the Illiac"
by W. C. Jacob, February 16, 1955.

"Stiefel's Methods for Solving Linear Equations"
by A. H. Taub, February 23, 1955.

Reports

Internal Report No. 61, "Computer Design Study: Access Time" by A. S. Douglas

"Operator's Manual for the Illiac" by W. L. Huffman

"Voltage-Drop Compensators for DC-Microammeters"
by W. J. Poppelbaum, submitted to RSI.

X. PERSONNEL.

The personnel associated with the group and hence the contributors to this report are:

Allen, Guy, Computer Operator I
Bateman, Wm. E., Jr. Electronics Technician (Term. March 30)
Breed, Charles P., Draftsman
Carter, Clifford E., Electronics Engineer for Illiac
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Clements, Virgil F., Jr. Laboratory Mechanic
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Douglas, Alexander S., Visiting Asst. Prof. of Math.
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The work of the group is under the administration of an Executive Committee with the following members: N. M. Newmark, Chairman, D. E. Muller, J. E. Robertson, A. S. Douglas, J. P. Nash, A. H. Taub, and R. E. Meagher.

R. E. Meagher
R. E. Meagher

REM/hc

UNIVERSITY OF ILLINOIS
GRADUATE COLLEGE
DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

Teaching and graduate research are not, in general, reported herein.

March 1 - March 31, 1955

I. MATHEMATICAL RESEARCH AND PROGRAMMING. (This work is supported in part by Task 30.)

Boolean Algebra

Further work has been done in connection with the treatment of dynamic switching circuits. A process analogous to differentiation may be applied to Boolean functions which represent time dependent variables. A function

$$y = f(x_0, x_1, \ldots, x_{p-1})$$

may be differentiated to yield a new function

$$\Delta y = g(x_0, x_1, \ldots, x_{p-1}, \Delta x_0, \Delta x_1, \ldots \Delta x_{p-1})$$

The condition that y shall not be subject to race conditions turns out to be equivalent to the statement that g is a monotonic (or frontal) function of $\Delta x_o, \ldots \Delta x_{p-1}$. If different appearances of the same variable in f are treated as different variables in forming g one takes into account the possibility of race conditions which are purely internal to f. This is the first necessary and sufficient condition which has been obtained which appears to be usable in practice.

Extension of the analysis of the complexity of combinational circuits has been carried out. In Internal Report No. 46 the formula

$$K_1 \frac{2D}{p} \leq E(p) \leq K_2 Z^p$$

was shown to limit the maximum complexity of a single output, p input combinational circuit. (The constants K_1 and K_2 depend on the definition of complexity which is chosen and the basic set of decision elements.) This formula has now been sharpened to

$$K_1 \frac{2D}{p} \leq E(p) \leq K_2 \frac{2D}{p} \quad .$$

It seems likely that a similar formula can be obtained for the p input, q output case but the proof has not been completed yet.

Data Processing

The large use of Library Routine K 2 which calculates means, standard deviations, product moment correlations, variances and covariances, has made it desirable to prepare a version which uses the magnetic drum. This is now being done, and the method of scaling certain quantities is being improved at the same time.

Random Numbers

A routine for generating random numbers by a method which is a modification of one recommended by Tocher has been written. This routine passed the preliminary tests for randomness very well and has the advantage over the middle-of-the-square method now in use that the sequence of numbers obtained is, for all practical purposes, endless. The routine is also three times faster than the middle-of-the-square routine. Frequency chi-square tests and poker tests on both routines have been run on a comparative basis in anticipation of an internal report.

It has been noted that since the process by which the random numbers are generated is reversible, the sequence of numbers, being finite, must form a single continuous loop. It is conjectured that this fact gives assurance of a relatively longer sequence, and information about this and similar properties of the process are being sought. The problem can be formulated as that of finding the matrix A and the vector v, over the ring of integers modulo 2^{40}, such that m in the equation

$$vA^m = v$$

is a maximum.

Linear Systems

A complete program is being tested for inverting matrices or for solving the matrix equation AX = B. This program uses electrostatic storage only and is limited to inverting matrices of order 22 or less and to solving

equations with $nm + n(n+1)/2 + n + m < 842$, where A is of size $(n \times n)$ and B of size $(n \times m)$. A possible case is $n = 30$, $m = 11$.

The conjugate gradient method of solving simultaneous equations is being considered for use in solving systems in which there are large numbers of zero coefficients so that it will be possible to take advantage of marking techniques for coefficient storage.

Floating Address Routine

Parts II and III and part of part VI as described in the last report have been written and part IV is now being prepared.

Numerical Differentiation

A reformulation of the equations used in Neville's interpolation formula permits much better accuracy than does direct use of the original equations. There is still some question about which of two options will be selected, and this will be decided as the actual programming develops.

Programming Manual

A third printing of Illiac Programming is being prepared. This printing includes a new chapter on checking.

II. ANALYTICAL PROGRAM. (This work is supported in part by NSF Grant G-1221.)

Work on differential equations of the Sturm-Liouville type is continuing along the lines described in the report for February, 1955. A method has been found for approximating the Lagrangean integral leading to the Sturm-Liouville differential equations such that the resulting difference equations are a second order approximation to these differential equations. It is planned to make some numerical experiments to test the accuracy of this and other related methods for solving the Sturm-Liouville differential equations.

III. LIBRARY ROUTINES.

During March the following program was added to the active Illiac Library:

0 6 (177)	Punch to Cathode Ray Tube Conversion Program. 175 + 3n words. This program displays on the cathode ray tube output material which has been programmed for the printer. Blocking orders are placed in all words containing punch orders (assumed to be n in number) and it is possible to display a format identical to one programmed for printer output subject to a limitation of 36 characters per line. Speed is about 45 characters per second.

IV. MACHINE USE.

During March 24 new problem specifications were presented as given below. This list does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 516. Numbers followed by T are for thesis problems.

516 Psychology. A study of the semantic factor structure of normal, neurotic and multiple personalities. The data will be analyzed through product moment correlations, principle components, factor analysis, and quartimax rotation of axes.

517 Agricultural Economics. Input-output analysis. Leontief's input-output analysis is used to study aggregate data for five sectors of the economy including two sectors of agriculture which are set up into a table of resource flows among the factors.

518 Electrical Engineering. Theoretical homing system. Performance calculations are made for certain ideal antennas when they are operating in a system which is designed for aircraft homing.

519 Agronomy. Sum check for data tapes. This program provides a sum check for data tapes prepared for use with randomized block analysis programs.

520 T Physics. Stored energy. This program is one of reduction of data obtained in the study of stored energy in the cold-working of copper with a temperature range from that of liquid nitrogen to room temperature.

521 Animal Science. Cross-breeding, creep-feeding and pasture effects on gilts and litters. This program uses library routines for solving linear algebraic equations and inverting matrices in order to analyze the data.

522 Institute of Communications Research. Factor analysis of distance relations among semantic judgments. This problem is concerned with an experiment in familiarity relations among semantic judgments and uses the principle axes method of analysis.

523 Control Systems Laboratory. Definite integral. Simpson's rule is used with the floating point routine to evaluate a complicated definite integral involving modified Bessel functions.

524 Physics. Sodium Vacancy. The radial part of the Schroedinger equation for a repulsive potential in a self-consistent field is solved.

525 Institute of Communications Research. Factor of F-scale items. The principle components of the correlation matrix for 29 items on the F-scale are found.

526 T Electrical Engineering. Transient response of a second-order servomechanism with friction-controlled backlash. The computation is for a system which is under-damped for all values of the parameters being varied. This type of non-linear servo obeys one of four linear differential equations depending on the values of the dependent variables and the past history of the system.

527 Physics. Analysis of scattering data. The program takes second differences of data for single and multiple cells, adds their absolute values and eliminates from the mean all the individual readings greater than four times the mean.

528 T Physics. Photonuclear cross-section analysis. The program computes Bremsstrahlung parts and calculates a matrix operator for obtaining photonuclear cross-sections. The results are then used to calculate weighting functions to describe a solution given by the matrix operator.

529 Animal Science. Methods of feeding swine. Simultaneous equations and matrix inversion routines are used to analyze experimantal data.

530 Education. Sequential analysis. The general problem is to specify how to select persons using a test where the test may be given repeatedly to doubtful cases until a decision is reached. It is desired to find the optimum procedure for any given selection ratio and cost of testing.

531 Institute of Communications Research. Quartimax rotation.

532 Bureau of Educational Research. Intercorrelation of social perception measures. Teacher and class characteristics of 4th, 5th, and 6th grades of an Illinois city are intercorrelated. Scores for 103 teachers were obtained on 38 variables.

533 Structural Research. Natural frequencies and mode shapes of a shear beam with equal masses.

534 Psychology. Multiple correlation. The problem is to determine from 15 predictors using multiple correlation, the best combination of predictors to give the most accurate prediction of 9 criteria variables.

535 T Structural Research. Lateral buckling of beams. Finite differences and a successive approximation method are used to solve integro-differential equations having boundary equations involving eigenvalues. Both the eigenvalue and its square are involved.

536 Psychology. Reliability of pattern classification. Two binary agreement pattern analyses are computed, one for a sample of 54 "good" mechanics, and the other for 46 "poor" mechanics. Results are compared with results previously obtained by the same procedure in order to estimate the reliability of classification of individuals with this method.

537 T Education. Correlates of favorable perception of teachers. Data concerning the favorability of children's perceptions of their teachers have been gathered from children in 20 classroom groups. By concurrent testing data have been obtained from the same children on a number of other variables. The problem involves obtaining product moment correlations, means and standard deviations of 24 variables for each of these 20 groups.

538 Institute for Research on Exceptional Children. Characteristics of brain-injured children. Pearson's correlation matrix and statistical analyses are obtained to determine the characteristics of brain-injured children.

539 Agronomy. Predicting double-cross performance. By use of performance data, it is possible to predict the outcome of 630 double-crosses. The program carries out the selection of cross combinations and calculates the predicted values.

Table I shows distribution of machine time for March.

TABLE I

Regular Maintenance and Illiac Engineering (usually 8:00 A.M. - 12:00 N)	60:53
Unscheduled Maintenance or Repair	9:52
Drum Engineering	41:46
R.A.R.	4:50
Leapfrog	49:44
Wasted	:33
Computer Use by Departments	
Computer Group	29:03
Classes	13:36
Physics	36:05
C.S.L.	63:25
Structural Research	23:18
Structural Research (AF 24944)	66:51
Structural Research (Nobs 62250)	18:04
Psychology	11:54
Psychology (AF 25726A)	11:39
Education	7:05
Electrical Engineering	7:40
Chemistry	22:00
Agriculture	19:21
Cosmotron	48:50
Purdue University	1:20
Indiana University	2:23
University of Illinois Medical College	2:09
Demonstrations	12:12
Miscellaneous	14:42
Total	579:15

V. ERROR FREQUENCY AND ANALYSIS.

The machine is normally used for "engineering" and maintenance between 8:00 A.M. and 12:00 N, and for a check of its performance between 5:00 and 5:30 P.M. of each weekday. Since the periods between 8:00 A.M. and noon, together with certain irregular periods like Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more instructive from an error analysis standpoint to look at the periods between noon and 8:00 A.M. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind, a summary table has been prepared using the period between noon and 8:00 A.M. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 5:00-5:30 P.M. period (when the machine is checked) if no errors are found, the time is given to the "running column." Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that any interruption of machine time that was not planned for is considered a failure in this table. In rare cases where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This overall system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" at any instant of time and the probability of a failure during any given interval of running time.

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
3/1/55	19:48	:08	1	(1) Leapfrog. Reader error.	:04	:55	1
3/2/55	18:06	1:51	3	(1) Leapfrog. Punch making fuzzy holes. (2) Probably Reader "E" made error. (Leapfrog) (3) Probably reader error.	:03	1:18	2
3/3/55	19:45	:15	2	(1) Leapfrog-Division failure. (2) Stopped on 81 order (No other information)	:00	1:12	1
3/4/55	20:00	:00	0		:00	1:04	0
3/7/55	20:00	:00	0		:00	1:28	0
3/8/55	19:59	:00	0		:01	1:09	0
3/9/55	19:55	:02	2	(1) Chad chute clogged on punch. (2) Unknown.	:03	1:04	0
3/10/55	19:53	:07	2	(1) Clutch on Reader "E" out of adjustment. (2) Computer stalled on legitimate orders.	:00	:57	0
3/11/55	17:25	2:35	3	(1) Reader "D" tore tape. (2) Reader "D" had both clutch and brake on at same time. (3) Bad solder connection on "B" in memory synch. chassis caused stalling.	:00	1:16	0
3/14/55	19:55	:01	1	(1) Two different results from same tapes.	:04	:56	0
3/15/55	20:00	:00	0		:00	1:31	0
3/16/55	19:59	:01	1	(1) Leapfrog-Punch error.	:00	1:26	1
3/17/55	19:46	:12	3	(1) Two different results from same tapes, (2) Unknown. (3) Punch "2" punched on extra 4 hole.	:02	1:45	1
3/18/55	19:57	:01	1	(1) Two different results from same tapes.	:02	1:01	0
3/21/55	19:50	:10	2	(1) Unknown but suspected to be due to reader error. (2) Punch error from new high-speed punch.	:00	1:01	0

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
3/22/55	19:36	:21	1	(1) Drive belt of high-speed punch broke.	:03	:53	0
3/23/55	19:44	:16	1	(1) Extra character from high-speed punch.	:00	1:49	0
3/24/55	19:59	:09	1	(1) New punch tore tape.	:00	1:10	0
3/25/55	19:57	:03	1	(1) Reader did not read in tape.	:00	1:01	0
3/28/55	19:59	:09	5	(1) Mass $0 \to 1$ memory failure 2^{-25}. (2) Reader "D" tore tape in two. (3) Reader "D" tore tape in two. (4) Reader "D" tore tape in two. (5) R ader "D" tore tape in two.	:00	1:05	1
3/29/55	19:57	:03	3	(1) Unknown. (2) Unknown. (3) Unknown.	:00	1:47	0
3/30/55	19:55	:03	1	(1) Error in "4" hole from high-speed punch.	:02	1:56	1
3/31/55	20:00	:00	0		:00	2:02	0
	453:17	6:19	34		:24	29:46	8

VI. COMMENTS ON THE ILLIAC AND RELATED FACILITIES.

The temporary 2048 word drum storage unit was used with the Illiac during the month. Tube replacements during the month included the following:

6AU6	20	6J6	7	Total	50
6BQ7	12	6AL5	1		
815	9	5687	1		

Maintenance difficulties encountered with the unit were as follows:

		No. of Tubes Replaced
March 1-2	Out of synchronization	3
March 4-5	Broken pin (intermittently open) in RG 14	4
March 8-10	Routine maintenance (low gain tolerance ratio)	10
March 10	Faulty recording (S_1 cathode follower) (3 815 plate caps broken)	5
March 14	Out of synchronization	2
March 15	Open filament CN9	1
March 21-22	Routine maintenance	20
March 28	Playback errors (open filament 01 amp.)	3
March 31	Routine maintenance	2

With the exception of the synchronization difficulties, most troubles were localized using the drum test code. Tubes in the indicated area were checked and those not meeting original specifications were replaced.

Gain tolerance ratios were as follows:

March	1	8	8	16	17	21	22	30	31
00 amplifier	1.3	1.3	1.6	1.4	1.7	1.4	1.5	1.6	1.6
01 amplifier	1.4	1.6	1.6	1.5	1.5	1.5	1.6	1.4	1.5

The gain tolerance ratio is the ratio of highest to lowest amplifier gains permitting satisfactory operation using drum test codes.

The enforced delay time was reduced from two word-intervals to one word-interval early in the month.

Work continued on the 60-character per second Teletype punches. After making some additional mechanical adjustments it was found possible to make the punches work fairly reliably. However, errors still sometimes occurred and these were traced to be due to the fact that the contacts corresponding to our "A" and "B" gates occasionally bounced and produced extra gates. When this happened, the punch results could be in error. It now seems evident that it will be necessary to mount light sources and photo tubes on the punches in order that proper "A" and "B" gates can be formed with high reliability.

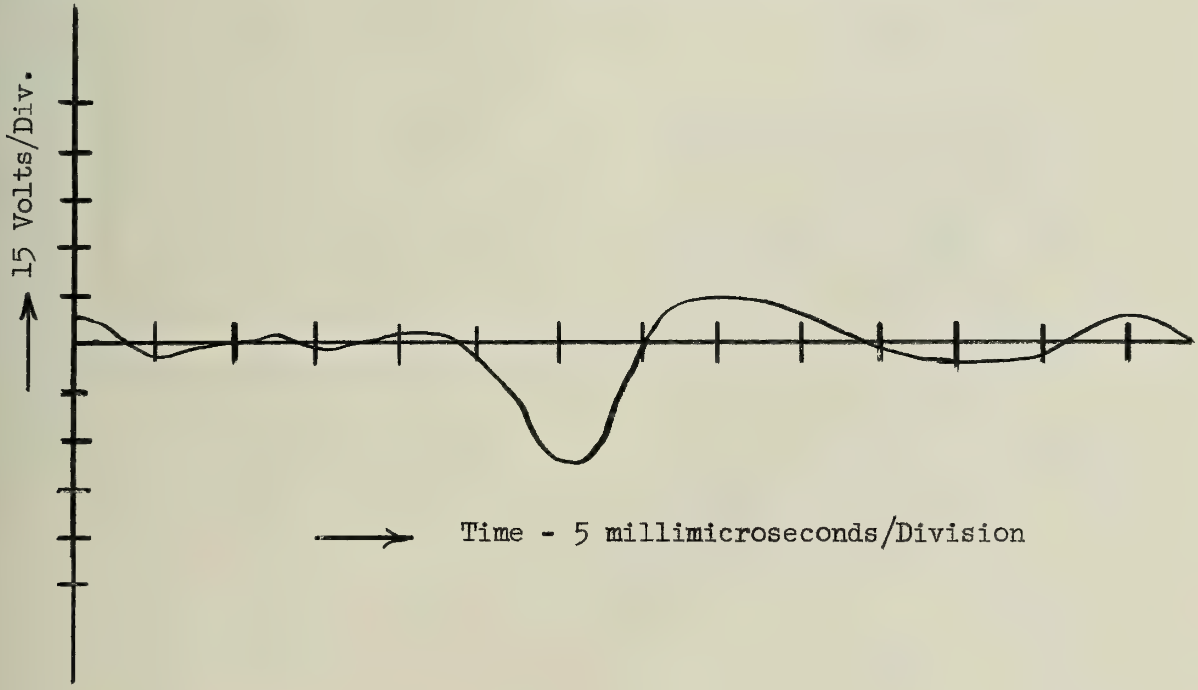
A Model 28 Teletype printer, together with the corresponding transmitter-distributor, has been assembled and put into operation on a trial basis. If this printer is to be used directly from the Illiac, it may be necessary to alter some of the printer control circuits before it can be considered satisfactory. If this is the case, it is probable that the printer will be operated as a printing unit from Teletype tape only.

VIII. RESEARCH ON COMPUTER COMPONENTS. (This work is supported in part by ONR Contract N6ori-07124.)

High-Speed Vacuum Tube Circuits

A satisfactory driver for high-speed shift registers was found and measurements of pulse wave shapes was made. The pulse chain is made by utilizing a pair of 807's as a push-pull oscillator as the primary signal source. These tubes generate a push-pull sine wave signal which was used to drive the horizontal deflection plates on the oscilloscope in order that a satisfactorily large sweep speed might be achieved. The signal from one of the 807 plates is ac-coupled to an EFP60 grid where it is dc-restored to the top of the signal by the grid diode. Since the sine wave signal is in excess

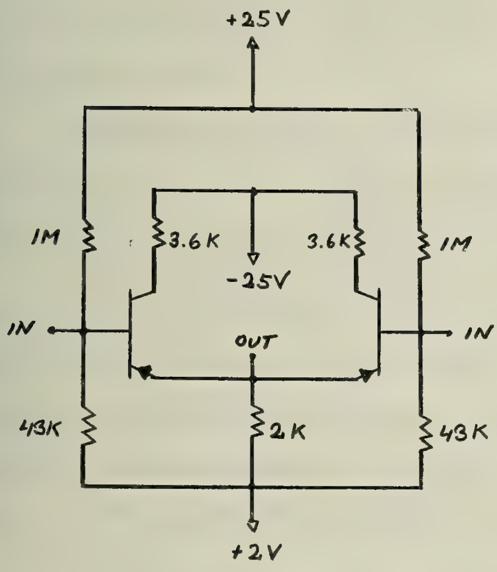
of 50 volts in amplitude, only a short spike appears at the EFP60 output. With a 15 mc oscillation, the pulse in the figure below was obtained. It was obtained using the oscillation as a sine wave sweep. It will be observed that the pulse is 11 millimicroseconds long from the point at which the signal falls until it rises again to that point. The fastest rise and fall times are on the order of 10 volts per millimicrosecond. Were this coupled directly to a low swing flipflop, this would yield the desired 10^{-8} second action times. It is planned to use two such drivers, one off each of the 807 plates, to obtain two pulses per cycle. These will appear on different lines and may be used as a pair of gate drivers in the normal up-down shifting scheme.



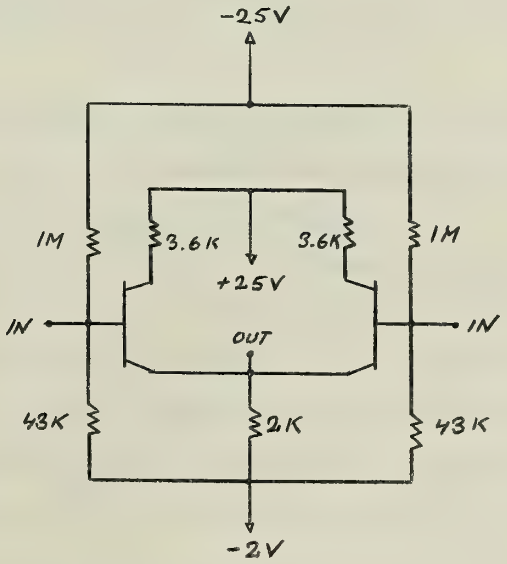
Direct-Coupled Transistor Circuits

A test instrument has been received from the shop and put into service after some modifications, necessitated by the noise level in the high-impedance circuits. This instrument gives the parameters r_b, r_e, r_c and α of npn and pnp transistors by direct reading on the scale of a vacuum tube voltmeter.

We have built a half-adder using our standard *and*, *or*, and *not* circuits; the output voltages are somewhat low, but well within the signal level limits discussed in the January report. However it has been decided to abandon the diode *and* and *or* circuits in favor of all-transistor units, the latter having voltage drops of ~50 mv as compared to the 200-500 mv drop of diodes. This step is justified by an important drop in the prices of transistors. The types 2N45 by General Electric and 200 by Texas Instruments have come down to a level which compares to that of diodes. The new *and* and *or* circuits are given in the figure below.



AND



OR

The work on the four-bit adder is in good progress: 16 flipflops and 10 *not* circuits have been wired and tested. We think that the *and* and *or* circuits and the chassis will be ready by the middle of April. These units will be built in such a fashion that the ulterior adjunction of multiplying facilities (Q-register, shift sequencing control, start-stop control, gates, etc.) does not bring about too much rewiring.

VIII. CONSTRUCTION.

Two of the tape guide plates for the six new photoelectric tape readers have been finished and final assembly of the first reader has been started. The other four tape guides have been roughed out and are now in the process of being finished. The time consumed in making there parts was much greater than was expected due to the hardness of the material used and the inability to procure milling cutters of a quality sufficient to keep a cutting edge. Ten new soft-rubber drive drums were made for the four old readers we well as the six new ones. Six new drive arm rollers without ridges were made, but upon inspection it was found that they were not true and would have to be made over. Reader "D" and Reader "E" were modified for a new soft-rubber drive drum.

The photoelectric tape comparer was made ready for use by building a frame around it, and covers were made for it. Several wiring changes were made. Then it was installed in the Teletype Room and wired up.

Thirty long pin bearings for the doors of the final drum unit were made up. The only other work on the drum unit was several drawings being made for parts of the unit. About half of the drawings for this unit are finished. The new word counter, Dwg. 596, was finished, and all parts for four new chassis, Dwgs. 471, 477, 478, and 534 have been made up and are ready to be assembled and wired. Layout prints of the final drum unit are now available.

The new drum from Engineering Research Associates has been received and unpacked, assembled and mounted to be used in the drum test unit. A frame and cover were made for it and installed. Both drums were wired up so that either unit can be used as desired.

IX. REPORTS AND SEMINARS.

Seminars

"Use of Implicit Boolean Function in the Design of Dynamic Switching Circuits," by David E. Muller, March 2, 1955.

"Boolean Matrices and the Design of Switching Circuits," by Franz E. Hohn, March 16, 1955.

"Two Illiac Library Routines," by Carl C. Farrington and Jerome H. Fishel, March 16, 1955.

"The Propagation of Error in Numerical Integrations," by A. H. Taub, March 23, 1955.

"A Numerical Solution to a Class of Sturm-Liouville Systems" by Robert T. Gregory, March 30, 1955.

Reports

Internal Report No. 62, "Operating Instructions for Photoelectric Tape Comparer," by R. E. Miller

Internal Report No. 63, "A Brief Description of the Routines in the Illiac Active Program Library," Part I, by Robert T. Gregory.

"A High Speed Permanent Storage Device," IRE Trans. on Electronic Computers, EC-4, pp. 16-20, March, 1955, J. M. Wier.

X. PERSONNEL.

The personnel associated with the group and hence the contributors to this report are:

Allen, Guy, Computer Operator I
Bateman, Wm. E., Jr. Electronics Technician (Term. March 30)
Breed, Charles P., Draftsman
Carter, Clifford E., Electronics Engineer for Illiac
Clark, Miss Helen B., Secretary I
Clements, Virgil F., Jr. Laboratory Mechanic
Cole, Douglas, 1/2 time Visiting Asst. Prof. of E. E.
Douglas, Alexander S., Visiting Asst. Prof. of Math.
Eadie, Miss Iva Jean, Student Assistant
Farrington, Carl C., 1/2 time Research Assistant
Fetzner, Mrs. Muriel P., Computer Teletype Operator
Fishel, Jerome H., 1/2 time Research Assistant
Frank, Werner L., 1/2 time Research Assistant
Germain, Jack H., Jr. Electronics Technician (Started April 1)
Golub, Gene H., 1/2 time Research Assistant
Gregory, Robert T., 1/2 time Research Assistant

Hill, Robert S., Student Assistant
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Kerkering, Thomas E., Sr. Laboratory Mechanic
Lopeman, Harold E., Electronics Engineer for Illiac
McGinnis, Gerald A., Sr. Electronics Technician
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Muller, David E., Res. Asst. Prof. of Applied Math.
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Poppelbaum, W. J., Research Associate
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Russell, Miss Ramona J., Computer Operator I
Schneberger, Edward J., 1/2 time Research Assistant
Seshu, Mrs. Lily, 1/2 time Research Assistant
Stephens, Allen, Jr. Laboratory Mechanic
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Wenta, Joseph, Sr. Electronics Technician
Wier, Joseph M., Research Associate (3/4 time)
Yii, Roland H.C., 1/2 time Research Assistant
Yu, Hwa-Nien, 1/2 time Research Assistant

The work of the group is under the administration of an Executive Committee with the following members: N. M. Newmark, Chairman, D. E. Muller, J. E. Robertson, A. S. Douglas, J. P. Nash, A. H. Taub, and R. E. Meagher.

R. E. Meagher.

R. E. Meagher

REM/hc

UNIVERSITY OF ILLINOIS
GRADUATE COLLEGE
DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

Teaching and graduate research are
not, in general, reported herein.

April 1 - April 30, 1955

I. MATHEMATICAL RESEARCH AND PROGRAMMING. (This work is supported in part by the Office of Naval Research under Contract N6ori-07130.)

Boolean Algebra

The work on the complexity of combinational circuits which was described in last month's report has been extended to the multiple output case. At the same time the proofs have been simplified and shortened. The present formula for maximum complexity of a p input and q output circuit E(p,q) is bounded by

$$C_1 \frac{2^r}{r} \leq E(p,q) \leq C_2 \frac{2^r}{r}$$

where $r = p + \log_2 q$ with C_1 and C_2 constants which are independent of p and q. This work is now being written up.

Random Numbers

A report on generating pseudo-random numbers is now being prepared. The character of the sequence formed by taking a linear combination of a fixed number of preceding terms is quite predictable and it is possible to determine the length of sequence. Another method used is not analyzable in the same way, but it has been found empirically that the sequence does not repeat in the first ten million numbers.

Statistical Applications

A routine which makes use of the magnetic drum has been written to find correlations and the variance-covariance matrix. The drum is used only when necessary and is not used at all when the number of variables is small. The routine, even without drum use, is slower than K2 because of additional bookkeeping requirements.

Linear Equations and Matrices

The program for solving linear matrix equations has been checked and is being prepared for the program library. The accuracy seems to be better than that of the present library routines.

Correction

In the report for March 1 - March 31 the inequalities on page one should read

$$K_1 \frac{2^p}{p} \leq E(p) \leq K_2 2^p$$

and

$$K_1 \frac{2^p}{p} \leq E(p) \leq K_2 \frac{2^p}{p} .$$

II. ANALYTICAL PROGRAM. (This work is supported in part by NSF Grant G-1221.)

Numerical experiments on various variational methods for solving a Sturm-Liouville ordinary differential equation are in progress. It has been shown that the variational method which leads to a second-order finite difference approximation to the differential equation can be modified to give a better approximation to the lowest proper value in the case of the equation

$$y'' + ky = 0 \qquad [y(0) = y(1) = 0].$$

Thus the closeness of approximation to the differential equation does not give criteria for selecting the best variational approximations. The variational methods will be applied to other examples for which solutions are known.

III. LIBRARY ROUTINES.

During April the following three programs were added to the active Illiac Library:

V 4 (178)	Fourier Analysis. 52 words. This is a closed routine which, given values of f(x) at equal intervals between 0 and L, computes the coefficients of the sine or cosine Fourier expansion. Library Routine T 5 is used to compute sine and cosine values. The time required to compute m terms of the sine or cosine series is $m^2 + 13m$ milliseconds.

N 8 (181) Read One Number from Tape as an Integer or Fraction. 22 words. This closed routine requires no preset or program parameters. Numbers are separated on the input tape by a marker consisting of a character using a fifth hole. The number (containing from one to twelve decimal digits) will be placed as a signed integer in A and as a signed fraction in Q. Accuracy is 2^{-40} for fractions, and integers are converted exactly. The conversion time is 3 milliseconds per digit so there is no cost in time with the present input speed of 250 characters per second which allows approximately 4 milliseconds beween each character.

K 5 (182) Autocorrelations. Entire Program. Designed to accomodate up to 795 observations, this program will compute any one of four types of autocorrelation, depending upon a parameter provided on the data tape. The printed results give type of autocorrelation, mean, and variance followed by two columns giving lag (by increments of unity) and autocorrelation. Computation time varies with the kind of autocorrelation but does not exceed about 45 seconds for the maximum number of observations in the most complicated case. Input and output time vary with the number of decimal places in the data (up to 12) and in the results (up to 9).

IV. MACHINE USE.

During April 13 new problem specifications were presented as given below. This list does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 540. Numbers followed by T are for thesis problems.

540 Cosmotron. Minimization of a function of 4 variables. The problem uses Library Routine H 4 to find a minimum of a quotient of two polynomials in 4 variables. There are 3 parameters and minimum values are desired in 2,700 combinations of the parameters.

541 Psychology. Test of consistency of psychological solution of centroid factor analyses. The problem finds quartimax solutions for 12 centroid factors and sums of squares of data and quartimax results.

542 Institute for Research on Exceptional Children. Effect of mentally retarded children on family integration. The analysis is carried out by computation of means and standard deviations and of a 22-variable Pearson product moment correlation matrix.

543 Bureau of Educational Research. Chi-square analysis of pupils' problems. With data from a form filled out by elementary school children, the analysis is directed toward comparing pupils' descriptions of their problems and the predictions of their responses by their teachers.

544 T Sociology. Study of relationship between attitudes and values. From a sample of 200 individuals there will be calculated a correlation matrix of order 22 consisting of attitude and value variables. Results will be used to show the relationship between performance on an accredited attitude scale and a scale of values.

545 T Economics. Maximum likelihood estimates of coefficients in simultaneous equations systems. This problem is devoted to a study of the bias in coefficients obtained from observed data. A sample study will be made by construction of synthetic data and insertion of known sample values of synthetic errors of measurement.

546 University Council on Teacher Education. Prediction of academic success. The McQuitty criterion pattern analysis method will be applied to a random sample of size 100 from the population of Champaign High School graduates. It is desired to predict grade point averages in the University of Illinois from high school grades in 55 courses.

547 Electrical Engineering. Effective permeability of a prolate spheroidal shell. The magnetic flux ϕ_0 through a circular wire loop in a static magnetic field is compared with the total flux ϕ_s passing through the loop when a prolate spheroid shell of known permeability and dimensions is passed inside the loop.

548 T Computer and Mathematics. Sturm-Liouville system. The general second-order differential equation with an eigenvalue λ

$$\frac{d}{dx}\left[p(x)\frac{dy}{dx}\right] + [q(x) + \lambda r(x)]y = 0$$

with associated boundary conditions on a finite interval (a,b)

$$y(a) = y(b) = 0$$

and the normalizing condition

$$\int_a^b r(x)\,y^2 dx = 1 \qquad [r(x) > 0 \text{ over } (a,b)]$$

is solved by introducing an analogous problem in the discrete calculus.

549 Student Counseling Bureau. Test validation study. By calculating Pearson product moment correlations and carrying out multiple correlations and factor analyses, a study will be made of prediction of grades in various courses in the University of Illinois College of Engineering during the freshman year using freshman guidance examinations as a basis.

550 Physics. Calculation of lattice sums. The floating point routine is being used to evaluate a sum of exponentials and trigonometric functions of a two-dimensional set of points in an area.

551 T Electrical Engineering. Third order servo with friction-controlled backlash. The Runge-Kutta method is being used to solve a set of four third-order differential equations which are solved successively to give the transient response of a third-order servomechanism following the application of a unit step input.

552 T Economics. Stability of dynamic economic systems. By solving systems of difference equations and evaluating roots of polynomials of the 17th defree, a study is being made of the stability of a dynamic economic system as affected by the length of the investment planning period as a multiple of the income period.

Table I shows distribution of machine time for April.

TABLE I

Regular Maintenance and Illiac Engineering	59:45
Unscheduled Maintenance or Repair	31:36
Drum Engineering	13:56
R.A.R.	5:58
Leapfrog	52:03
Wasted	4:13
Computer Use by Departments	
Computer Group	19:57
Classes	15:35
Physics	34:47
C.S.L.	60:40
Structural Research	12:30
Structural Research (AF 24994)	5:49
Structural Research (Nobs 62250)	29:24
Psychology	4:24
Psychology (AF 25726A)	11:32
Education	5:37
Electrical Engineering	19:26
Chemistry	60:47
Agriculture	15:15
Cosmotron	32:29
Purdue University	:10
Harvard University	5:26
Miscellaneous	7:18
Demonstrations	:18
Total	508:55

V. ERROR FREQUENCY AND ANALYSIS.

The machine is normally used for "engineering" and maintenance between 8:00 A.M. and 12:00 N, and for a check of its performance between 5:00 and 5:30 P.M. of each weekday. Since the periods between 8:00 A.M. and noon, together with certain irregular periods like Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more instructive from an error analysis standpoint to look at the periods between noon and 8:00 A.M. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind, a summary table has been prepared using the period between noon and 8:00 A.M. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 5:00-5:30 P.M. period (when the machine is checked) if no errors are found, the time is given to the "running column." Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that any interruption of machine time that was not planned for is considered a failure in this table. In rare cases where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This overall system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" at any instant of time and the probability of a failure during any given interval of running time.

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
4/1/55	12:25	7:35	4	(1) Leapfrog memory error $0 \to 1$ 2^{-9} add 01L (Changed chassis in this position.) (2) Leapfrog. Input-output failure. Bad connection vicinity of U34. (3) Two different results from same tapes. (4) Leapfrog. Unknown.	:00	1:33	3
4/4/55	16:23	3:37	4	(1) New punch No. 3 broke tape. (2) New punch No. 3 error. (3) New punch No. 3 error. (4) New punch No. 3 error, leapfrog.	:00	1:02	1
4/5/55	18:20	1:31	4	(1) White switch was not making contact properly. (2) New punch No. 5 error. (3) New punch No. 5 error. (4) New punch No. 3 error.	:00	1:44	0
4/6/55	18:25	1:32	2	(1) Leapfrog. Unknown. (2) Apparently stopped on L7 on right-hand side.	:03	1:31	1
4/7/55	19:57	:00	0		:03	1:10	0
4/8/55	19:53	:00	1	(1) Hung up on a read order from OSJ.	:06	1:18	0
4/11/55	19:57	:01	1	(1) Error in 2^{-34} $0 \to 1$.	:02	2:36	0
4/12/55	20:00	:00	0		:00	1:40	0
4/13/55	19:57	:01	1	(1) Two different results from same tape. Suspect Reader "F" error.	:02	1:09	0
4/14/55	19:55	:01	1	(1) Reader "F" reading incorrectly.	:04	1:15	0
4/15/55	18:52	1:02	1	(1) Leapfrog. Memory error 2^{-21} $0 \to 1$ Memory chassis changed.	:06	1:10	1
4/18/55	17:09	2:48	3	(1) Reader "F" reading incorrectly. (2) Would not read in DOI, $V42\text{-}R_3\text{-}2^{-4}$, 5844 Short $G_2\text{-}P_2$. (3) Punch No. 2 punched an extra 4 hole. (Leapfrog)	:03	:49	1

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
4/19/55	19:56	:02	2	(1) Reader "G" error. (2) Punch No. 2 punched extra 4 hole.	:02	1:41	0
4/20/55	19:53	:07	2	(1) Two different results from same tapes. (2) Two different results from same tapes.	:00	1:50	0
4/21/55	18:16	1:41	3	(1) Leapfrog. Machine error $0 \rightarrow 1$ 2^{-21} (2) Two different results from same tapes. Suspect Reader "E." (3) Reader "E" reading incorrectly.	:03	:53	1
4/22/55	20:00	:00	0		:00	1:31	0
4/25/55	19:57	:01	1	(1) Reader "G" replaced because a pin in brake was loose.	:02	1:02	0
4/26/55	19:59	:01	1	(1) Reader "H" error because of dirt in holes.	:00	1:41	0
4/27/55	19:40	:18	3	(1) Reading error. Reader "E." (2) Reading error. Reader "E." (3) Leapfrog. Memory error 2^{-21} $0 \rightarrow 1$	:02	1:24	1
4/28/55	15:13	4:47	4	(1) Computer error. Probably due to reason in (2). (2) Leapfrog. Memory error 2^{-2} $0 \rightarrow 1$ (changed position 2 chassis) (3) Leapfrog error. V10 add generator, no emission. (4) Reader "I" error.	:00	1:08	2
4/29/55	15:44	4:16	3	(1) Two different results from same tape. (2) Leapfrog memory error. $0 \rightarrow 1$ 2^{-3} add 01F (Positions 3 and 4 chassis changed.) (3) Memory error. $0 \rightarrow 1$ in 2^{-25}	:00	:57	1
	389:34	29:39	41		:47	29:04	12

VI. COMMENTS ON THE ILLIAC AND RELATED FACILITIES.

During the month a new magnetic drum was received from the ERA Division of Remington Rand to replace our older drum. It is hoped that with the new drum a word density of 64 per track (2816 digits) may be used with the NRZ recording scheme which allowed 32 words per track on the older drum. If this can be done, the total number of words stored on the drum would amount to 12,800. The new drum has been operated for a short period of time using 8 tracks and a corresponding memory size of 512 words with a gain tolerance ratio of 1.3. In order to put this new drum into operation with the circuits which were operating with the previous drum, some changes were found necessary which are recorded here:

1) The input bleeders on the A and B control track amplifiers were made identical. The lower excursion of the output signal from each of these amplifiers has been clamped to prevent spurious triggering of the corresponding pulser.

2) The duration of the A and B pulses has been shortened to 1 μs.

3) The duration of the playback strobe delay has been changed to optimize the position of the playback strobe.

4) The word counter had to be revised to allow for 64 words per track.

5) The coupling capacitors in the preamplifiers and playback amplifiers have been decreased by a factor of two in certain places.

6) The capacitors in the switching smoothing circuits were decreased in size from 0.01 μfd to 0.005 μfd.

The control track pulses as recorded by ERA before the drum was delivered had certain minor errors which finally required that they be re-recorded.

Some additional characteristics of the new drum which may be of interest can be mentioned. The drum was supplied with a head-to-drum spacing estimated to be 0.002 inch. With this spacing, crosstalk was observed from one track to another. If a recording of 4KC is made on one

track then a signal on an adjacent track is obtained which is about 10% of a normal signal amplitude on that track. When a signal of about 80KC is recorded (which corresponds to the word density now being used) and when the head-to-drum spacing is retained at 0.002 inch then the 80KC signal observed from the track is about 70% of the 40KC signal which may be considered to be approximately the normal amplitude. If the head-to-drum spacing is reduced to approximately 0.0015 inch, then the 80KC signal is about 80% of the 40KC signal for that track. It is estimated that the head-to-drum spacing decreases by 0.0002 inch for a shell temperature rise of 17°C.

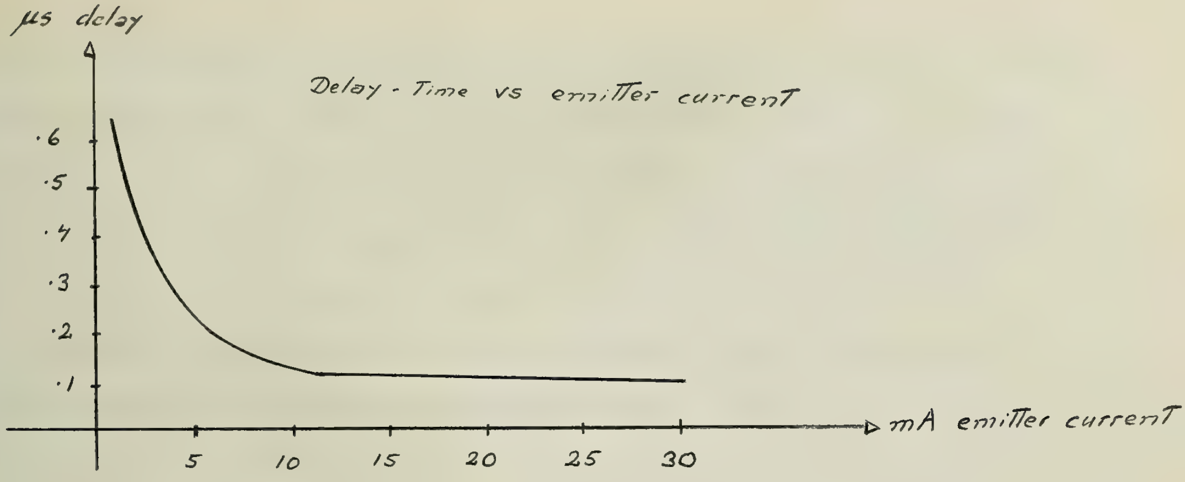
The Model 28 printer has been placed into service and as suggested in last month's report, it will be used in the Teletype Room rather than as a direct output from Illiac. This has been done because certain tolerance requirements would require that the output circuit from Illiac be redesigned if it were required to operate this printer directly.

VII. RESEARCH ON COMPUTER COMPONENTS. (This work is supported in part by the Office of Naval Research under Contract N6ori-07124.)

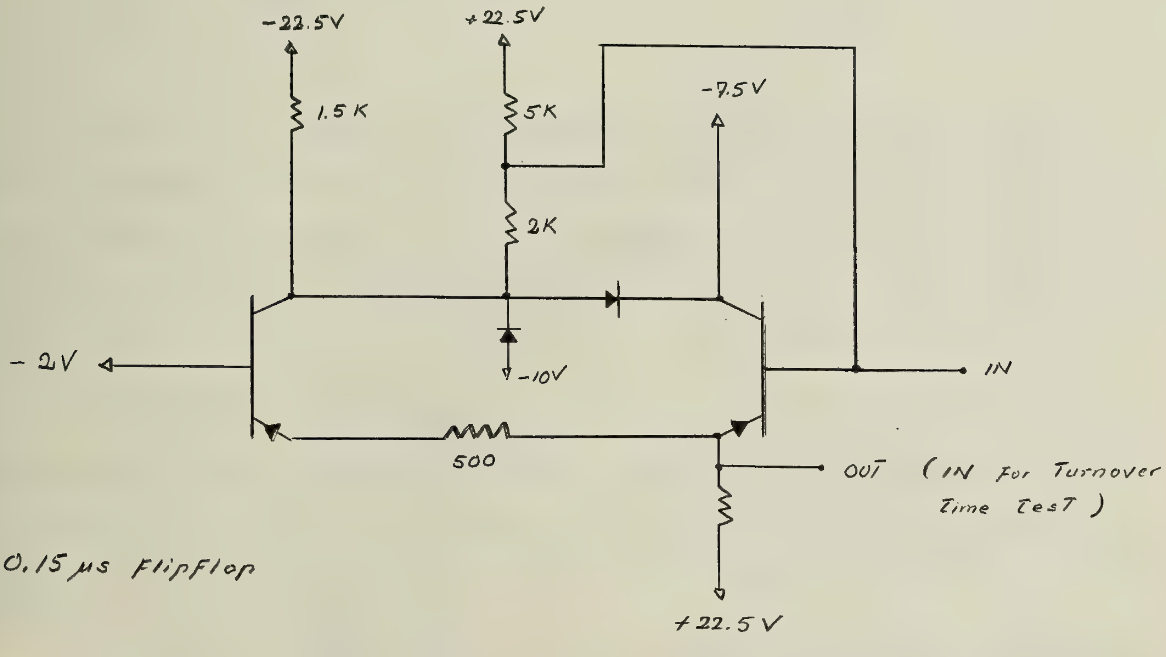
Direct-Coupled Transistor Circuits

During the month of April attention has been focused on new high-speed flipflops rather than on the development of more complex installations. Work on the adder-subtractor was temporarily stopped.

Theoretical work has been done on the physics of transistors in order to be able to use them under the best possible conditions as regards frequency response and delay time of the carrier in the base region. It was found that theoretically and practically the α cutoff frequency increases with increasing emitter current, while the time delay in the base decreases at the same time. This phenomenon appears to be independent of the collector voltage. For a certain 2N43 transistor the delay is given by the following graph.



Making use of this fact, a modified 2-transistor emitter-follower GB amplifier flipflop (see February issue of the Technical Progress Report) was built. The values of the elements are given in the following figure. With these values the turnover time was of the order of 0.15 µs.

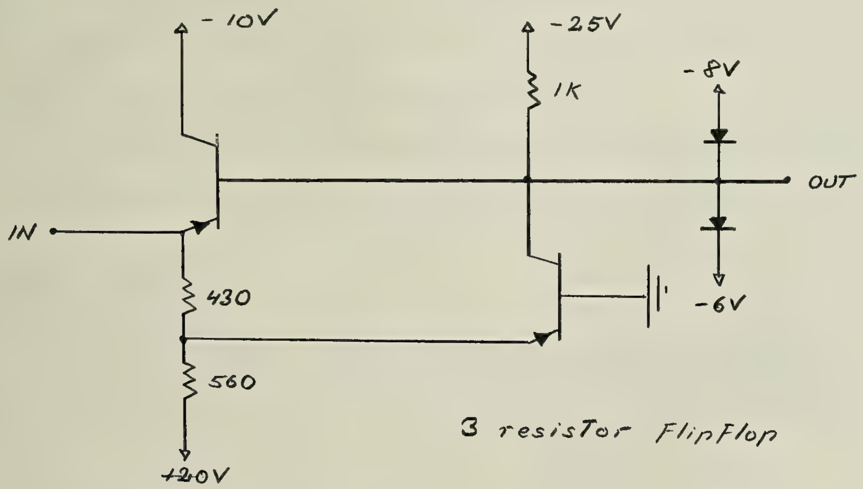


0.15 µs flipflop

It should be stated expressly that these times were obtained with transistors of the cheapest kind, having a (low emitter current) α cutoff frequency of 1 MC. Further it should be pointed out that the flipflop uses transistors of only one kind. This is important if it is to be adapted to

the new Si-transistors which can be obtained in the npn form exclusively. The average current in either of the two transistors is 20ma and neither one is ever cut off. The latter fact brings about an additional gain of time. There is a constant voltage drop $r_e i_e$ ($\sim$ 50mv) across the constant emitter-base capacitance ($\sim$ 3000 μμf), thus eliminating all charging currents. Near cutoff the device becomes non-linear.

Another two-transistor flipflop, characterized by the use of only three resistors, gave very promising results, too.



3 resistor Flipflop

It has the important property that by suitable triggering the three electrodes of the transistor are forced simultaneously toward the new state. The speed of such a device then depends only on the power used to drive it, i.e., the power of the gates. It is interesting to notice that the sum of the emitter currents in this device is constant. It has been found that this flipflop was developed independently by Henle of IBM.

The elegant Eccles-Jordan circuit developed by Philco for their surface-barrier units was tried out also. The announced turnover time of 0.35μs was obtained without difficulty. This saturating flipflop will be of more interest as soon as certain stability problems are overcome and the voltage swing somewhat increased.

A definition which takes account of computer uses was adopted for the turnover time of flipflops. First of all a last moving point is defined

for every trigger point. Then the flipflop is driven with an input voltage swing equal to its natural output swing. The turnover time is defined as the time elapsed between the beginning of the input pulse (at the input) and the instant when the output pulse has gone through 90% of the voltage change. This time can be decomposed into the delay time and the rise time of the circuit.

A set of preliminary investigations have been conducted on the use of transistors to drive magnetic cores. It has been found that the paralleling of several GE transistors gives much better waveforms than power transistors. With steel cores and 8 windings carrying 25ma maximum current, rise times were of the order of 3µs, the fall times being 10µs.

An internal report is being prepared giving full details about the circuit aspects and the physical aspects of fast junction transistor flipflops.

VIII. CONSTRUCTION.

The six new photoelectric tape readers, designated F, G, H, I, J and K have been finished. Although all of them have been tested on the Illiac, minor adjustments may still be necessary.

Reader B was dismantled so that it may be used as a test model for several ideas which may, if successful, be used on the other readers. It seems desirable to test a new clutch which would permit some adjustment outside the reader without removing the reader from its case, which is necessary at the present time. It may also be that a thin piece of glass can be inserted over all of the light holes to reduce the problem caused by dirt clogging up the holes.

The frame for the final drum unit has been started. The milling and machine work on the I-beams which furnish the lower supporting members for the unit are underway. Additional drawings and four new chassis associated with the drum unit have been assembled but not wired.

IX. REPORTS AND SEMINARS.

Seminars

"The Sieve Problem for All-purpose Computers," by
Carl C. Farrington, April 6, 1955.

Seminars (Cont.)

"Methods of Conjugate Gradients for Solving Linear Systems," by Raymond P. Polivka, April 20, 1955.

"The Design of Circuits for Very High-speed Electronic Digital Computers," by J. M. Wier, April 27, 1955.

X. PERSONNEL.

The personnel associated with the group and hence the contributors to this report are:

Allen, Guy, Computer Operator I
Breed, Charles P., Draftsman
Carter, Clifford E., Electronics Engineer for Illiac
Clark, Miss Helen B., Secretary I
Clements, Virgil F., Jr. Laboratory Mechanic
Cole, Douglas, 1/2 time Visiting Asst. Prof. of E. E.
Eadie, Miss Iva Jean, Student Assistant
Farrington, Carl C., 1/2 time Research Assistant
Fetzner, Mrs. Muriel P., Computer Teletype Operator
Fishel, Jerome H., 1/2 time Research Assistant
Frank, Werner L., 1/2 time Research Assistant
Germaine, Jack H., Jr. Electronics Technician (Started April 1)
Golub, Gene H., 1/2 time Research Assistant
Gregory, Robert T., 1/2 time Research Assistant
Hill, Robert S., Student Assistant
Huffman, Wm. L., Computer Operator II
Kerkering, Thomas E., Sr. Laboratory Mechanic
Lopeman, Harold E., Electronics Engineer for Illiac
McGinnis, Gerald A., Sr. Electronics Technician
Meagher, R. E., Chief Engineer
Michael, George W., Administrative Assistant
Miller, Raymond E., 1/2 time Research Assistant
Muller, David E., Res. Asst. Prof. of Applied Math.
Nash, J. P., Res. Prof. of Applied Math.
Newmark, N. M., Chairman, Executive Committee
Ogata, Albert I., Student Assistant
Pelg, Edmund, Jr. Electronics Technician
Polivka, Raymond P., 1/2 time Research Assistant
Poppelbaum, W. J., Research Associate
Robertson, James E., Res. Asst. Prof. of Elec. Eng.
Russell, Miss Ramona J., Computer Operator I
Schneberger, Edward J., 1/2 time Research Assistant
Seshu, Mrs. Lily H., 1/2 time Research Assistant

Stephens, Allen, Jr. Laboratory Mechanic
Taub, A. H., Res. Prof. of Applied Math.
Wenta, Joseph, Sr. Electronics Technician
Wier, Joseph M., Research Associate (3/4 time)
Yii, Roland H.C., 1/2 time Research Assistant
Yu, Hwa-Nien, 1/2 time Research Assistant

The work of the group is under the administration of an Executive Committee with the following members: N. M. Newmark, Chairman, D. E. Muller, J. E. Robertson, A. S. Douglas, J. P. Nash, A. H. Taub, and R. E. Meagher.

R. E. Meagher

R. E. Meagher

REM/hc

UNIVERSITY OF ILLINOIS
GRADUATE COLLEGE
DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

Teaching and graduate research are
not, in general, reported herein.

May 1 - May 31, 1955

I. MATHEMATICAL RESEARCH AND PROGRAMMING. (This work is supported in part by the Office of Naval Research under Contract N6ori-07130.

Boolean Algebra

An analogy has been found between electronic circuits and relay circuits of the type containing no secondary coils. The analogy offers the prospect of handling by algebraic methods relay circuits which are not of the series-parallel kind.

Random Numbers

A routine which uses the logical product order has been used to test groups of numbers (20 numbers per group were used) to see how long a sequence of numbers is needed before every binary digital position is occupied by a zero. The test is very rapid and very good results were obtained with Library Routine V 3 and with another routine that was tested for 10,000,000 numbers.

Differential Equations

A floating point version of the Runge-Kutta routine has been programmed to aid in the evaluation of certain statistical distributions for which it was found that the fixed-point routine gives extremely accurate results. Because of parameter variability a floating point routine is useful here. The speed is, of course, very slow.

Roots of Polynomials

A complex numbers floating point routine has been written to investigate a method proposed by Maehly for finding roots of polynomials. Investigations were made of the problems $\sum_{i=0}^{p} x^i = 0$, for cases p = 15, 31 and 63 as well as for a number of classical problems. In most cases excellent results were obtained. Difficulties arose (a) if the first and second derivatives of the polynomial vanished at zero, or (b) if the polynomial had multiple roots.

The first difficulty can be avoided by changing the initial approximation and the second can be met by changing the convergence criterion (the value was changed from 10^{-8} to about 10^{-5}) and accepting a loss in accuracy.

The method at present has the disadvantage that there are too many operations thus slowing things down considerably. It is necessary to evaluate $f(x_i)$, $f'(x_i)$ and $f''(x_i)$ at each operation, and this requires about 6n operations. It took about 50 minutes to solve $\sum_{i=0}^{63} x^i = 0$.

It may be possible to find a substitute for evaluating the derivatives which will speed up the computation. If not, the present method (Library Routine J 1) will be better.

II. ANALYTICAL PROGRAM. (This work is supported in part by National Science Foundation Grant G-1221.)

Further numerical experiments on variational methods for solving a Sturm-Liouville ordinary differential equation were made. An approximation to the differential operator was obtained by approximating the unknown function y(x) by a sequence of parabolic arcs with continuous values of the function and its derivative at the mesh points. This approximation to the function was substituted into the Lagrangian function and a quadratic form was obtained as an approximation to the integral to be varied. The resulting system of linear equations was solved numerically to determine approximations to the proper values and functional values at the mesh points for the case

$$y'' + ky = 0 \qquad [y(0) = y(1) = 0].$$

A mesh of 21 points was used. The error in the first proper value was less than 0.002%; in the first five less than 0.3%; in the first seven 1.4%; and in the first nine less than 7.6%. The functional values were correspondingly good. No spurious proper values and proper functions appeared as was the case in variational methods related to directly approximating the differential equation by difference equations.

III. LIBRARY ROUTINES.

During the past month the following two programs were added to the active Illiac Library. Library Routine M 15 was written by Mr. Leonard Isaacson of the Department of Chemistry and Chemical Engineering.

M 13 (179) Complete Linear Matrix Equation Solver and General Matrix Inversion. Entire Program. This program uses the elimination method to solve the matrix equation AX = B where A is non singular and square. If A is n by n and B is n by m, the sizes of A and B are limited by $nm + n(n+1)/2 + n + m < 842$. If B = I, then $X = A^{-1}$ and the limit is $n \leq 22$. Results are punched out by columns. Computing time for m = 1 is about $n^3/500$ milliseconds and for n = m is about $n^3/100$ milliseconds. A sample solution of a system of 38 equations in 38 unknowns with random integer coefficients required approximately 100 seconds of computing time and gave results with errors less than 10^{-10}.

M 15 (183) Linear Programming. Entire Program. This is a floating point program which can be used to maximize or minimize a linear functional subject to constraints in the form of a set of equalities or inequalities. The capacity of the routine is defined by $4(i+j) + ij \leq 708$ where i and j are the numbers of basis and structural vectors, respectively. Running time is not easy to predict, but problems utilizing nearly the full capacity have almost always required from 10 to 31 minutes, including input and output.

IV. MACHINE USE.

During May the following 36 new problem specifications were presented. This list does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 553. Numbers followed by T are for thesis problems.

553 T Structural Research. Numerical Solution of Shell Structures. A cylindrical shell problem is solved by a numerical approach using simultaneous linear equations which incorporate the use of a replacement structure of rigid bars in elastic joints.

554 Institute of Communications Research. Relation of F-Scale Scores to Mental Health Opinion Scores. A correlation matrix is obtained for a set of 17 variables in order to obtain an idea of the type and standard of relations between answers on F-scale items and the scores made on factors measuring opinion on mental health questions.

555 Physics. Calculation of Diffusion Coefficients from Experimental Data. The method of least squares is used in this computation.

566 T Structural Research. Approximate Analysis of Domes. Systems of simultaneous difference equations are solved to give deflections and stresses in symmetrically loaded rotational shells.

557 T Structural Research. Characteristic Roots and Vectors of Symmetric Lambda Matrices. The problem is to find the roots and associated characteristic vectors for the determinantal equation $|A| = 0$, where the elements a_{ij} of A are functions of λ and $a_{ij}(\lambda) = a_{ji}(\lambda)$.

558 Electrical Engineering. Wave Propagation in a Slotted Wave Guide. A trigonometric equation is solved in order to compute the complex propagation constant of an electromagnetic wave proceeding down an infinitely wide, uniformly slotted wave guide.

559 Agricultural Economics. Demand Analysis. This work is in connection with a demand analysis study. Artificially constructed examples are being used in an attempt to find what happens to estimates under varying assumptions. The method uses matrix multiplication routines to calculate residuals in a multiple correlation problem.

560 Agronomy. Multiple Regression Analysis. Data used with the routine will be concerned with various phases of agronomic research such as factors affecting yield of forage crops and factors affecting disease incidence in corn.

561 T Education. Cognitive Simplicity in Student Teachers. Correlation matrices will be used for comparison of good and poor student teachers' descriptions of students they taught in practice teaching.

562 Structural Research. Maximum Deflection of a Non-Linear System with Variable Coefficients. The program computes the maximum absolute value of the argument in a second order differential equation.

563 Bureau of Economic and Business Research. Multiple Regression of Service Expenditures on Other Variables. The problem is concerned with a study of consumer expenditures on particular service items as influenced by variables such as income, family size, etc.

564 Physics. Integral Equations for Meson-Nucleon Scattering. The problem consists of integrating a set of 3 equations in which 4 integrals occur as functions of the independent variable. The method is an iterative one.

565 T Physical Education. Environmental Performance Relationship. A multiple analysis method due to McQuitty is used to investigate possible relationships between environmental variables and physical performance standards of 100 college freshmen at the University of Illinois.

566 Theoretical and Applied Mechanics. Interaction Curves with Strain Hardening. By means of volume and moment calculations a study will be made of moments and forces of non-linear stress distributions with and without strain hardening.

567 Psychology. Pattern Analysis of Air Force Mechanics. Test responses of Air Force mechanics are compared in order to measure the number of items on which they agree.

568 Computer. Roots of Polynomials. This is a study of LeGuerre's method of finding roots of algebraic equations.

569 T Physics. Concentration of Di-vacancies in Quenching. The problem is concerned with crystal structure and the Runge-Kutta method is used in the integration of a resulting differential equation.

570 Computer. Floating Point Differential Equation Routine. This is a program which uses floating point notation in the Runge-Kutta method.

571 T Computer. Learning Device Model. This routine converts the Illiac into a serial machine with a very simple order code which is used to perform the set of basic operations necessary to compound more complex operations. By also "building in" a basic learning routine, it becomes possible to "teach" the machine more complex orders and thus to make it more versatile.

572 Mechanical Engineering. Pipe Sizing Charts for Steam Flow. A set of equations describing steam flow in pipes is being solved for the purpose of compiling a set of charts.

573 Accountancy. Production Selection. The method of linear programming is used to solve a problem in the selection of optimum production as a function of price, production, time periods, working hours and storage capacities.

574 Astronomy. Shock Waves in a Stellar Model. The problem is concerned with the motion and structure of spherical shock waves advancing through a medium in which the density is decreasing ahead of the shock front. It reduces to a solution of 3 differential equations, which are solved by the Runge-Kutta method.

575 Physics. Orthogonalized Plane Wave Calculation for Silicon Crystal. The problem is to determine solutions of the Schrödinger equation for an electron in an idealized perfect single crystal of silicon. It is necessary to carry out numerical evaluation of matrix elements, do similarity transformations of matrices, and to solve determinantal equations.

576 Physics. Superconductivity. A study is made of a simplified model for superconductivity suggested by Bardeen. Perturbation theory is used to determine the ground state for the system as a whole and a criterion for superconductivity is found as a function of the energy gap.

577 T Chemistry. Calculation of Sedimentation Coefficients. The problem is concerned with calculation of sedimentation coefficients in connection with ultracentrifuge work. Simpson's rule and a simultaneous equations routine are used to solve the integral equations.

578 Accountancy. Product Selection. The determination of a product to manufacture, given a range of products, time periods for manufacture, prices, restrictions on capacity, etc., will be made by using linear programming methods.

579 Computer. Product Moment Correlation Routine. This routine is a modification of Library Routine K 2 for use with the magnetic drum.

580 T Psychology. Configural versus standard Method of Scoring the Strong Vocational Interest Blank. This problem involves the development of configural scoring keys for seven occupational samples of fifty individuals each on a Strong Vocational Interest blank. These keys are to be compared with those used by Strong for accuracy in predicting occupational interests. The method used is that developed for McQuitty's method of similarity analysis and will be used to obtain a 50 x 50 matrix of agreement scores.

581 T Agricultural Economics. Farm Income. Multiple regression methods are used to analyze the income variability of live stock and grain farms during the period 1936-1953.

582 Agronomy. Fitting of Yield Curve. The problem is to fit a curve of exponential form to experimental data. The curve expresses the relation between yield, maximum yield, soil composition of a nutrient, and the added quantity of that nutrient.

583 Sociology. Cultural Structure of a College Community. A 94-variable product moment analysis and a centroid factor analysis involving 10-12 factors are used to make a macroscopic study of the total belief system of a small college community.

584 Structural Research. Differential Equation. The Runge-Kutta method is used for finding the solution of a second order non-linear differential equation.

585 Electrical Engineering. Annealing of Germanium by a Divacancy Mechanism. A pair of simultaneous differential equations is solved with the Runge-Kutta method to study theoretically the annealing of thermal defects in germanium.

586 Agricultural Economics. Demand Analysis. This is a refinement of the method used in Problem 559.

587 State Water Survey. Estimation of Lake Silting. The problem is concerned with obtaining an equation which will permit prediction of silt depositing in a lake from knowledge of water shed conditions. It will be solved as a multiple correlation and regression analysis involving eight variables.

588 Student Counseling Bureau. Scoring Strong Vocational Interest Blanks. The problem is to develop a program for scoring a Strong Vocational Interest blank in an effort to reduce substantially the amount of time now required.

Table I shows distribution of machine time for May.

TABLE I

Regular Maintenance and Illiac Engineering	58:42
Unscheduled Maintenance or Repair	16:55
Drum Engineering	12:53
R.A.R.	6:08
Leapfrog	65:55
Wasted	:54

TABLE I (Cont.)

Use by Departments

Computer Group	46:23
Classes	24:42
Physics	65:44
Control Systems Lab.	58:22
Structural Research (AF 24994)	30:50
Psychology	2:22
Psychology (AF 25726A)	3:32
Education	3:56
Electrical Engineering (AF 310)	:12
Chemistry	44:49
Agriculture	22:08
Cosmotron	36:12
Harvard University	5:25
Indiana University	:47
Miscellaneous	11:05
Demonstrations	2:06
TOTAL	543:35

V. ERROR FREQUENCY AND ANALYSIS.

The machine is normally used for "engineering" and maintenance between 8:00 A.M. and 12:00 N, and for a check of its performance between 6:00 and 6:30 P.M. of each weekday. Since the periods between 8:00 A.M. and noon, together with certain irregular periods like Saturdays and Sundays, are devoted to a heterogeneous group of functions. it is more instructive from an error analysis standpoint to look at the periods between noon and 8:00 A.M. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind, a summary table has been prepared using the period between noon and 8:00 A.M. of the next day. This table lists the

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
5/2/55	19:47	:08	2	(1) -300 v. power supply accidentally turned off. (2) Two different results from same tapes. May be a reader "C" error.	:05	1:09	0
5/3/55	19:16	:43	3	(1) Two different results from same tapes. (2) Reader "I" error. 2C51 replaced. (3) Reader "E" error. Voltage setting wrong.	:01	:33	0
5/4/55	20:00	:00	0		:00	1:21	0
5/5/55	20:00	:00	0		:00	1:17	0
5/6/55	18:35	1:17	1	(1) Run-over of morning maintenance looking for a control error which left and was not found	:08	3:54	0
5/9/55	15:52	4:05	2	(1) Two different results from same tapes; reader "F" error suspected. (2) Reader "F" error.	:03	1:09	0
5/10/55	19:47	:13	2	(1) Punch error, caused by broken wire in output rack. (2) Reader "J" error.	:00	1:59	0
5/11/55	18:55	1:05	4	(1) Two different results from same tapes. (2) Two different results from same tapes; reason not evident. (3) -300 v. power supply circuit breaker opened No reason known. (4) Leapfrog. Unknown.	:00	1:19	1
5/12/55	18:00	2:00	6	(1) Reader "K" stalling. (2) Reader "K" error. (3) Paper jammed in punch "3". (4) Reader "C" tore tape. (5) Reader "C" tore tape. (6) Leapfrog 2-1 failure.	:00	:46	1
5/13/55	19:50	:10	2	(1) Two different results from same tapes. (Error discovered later). (2) Punch "3" tape jammed.	:00	1:07	0

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
5/16/55	20:00	:00	0		:00	1:49	0
5/17/55	19:54	:06	3	(1) Punch "3" error. (Tape did not advance properly). (2) Punch "3" broke tape. (3) Punch "3" error (broken wire on B gate).	:00	1:51	1
5/18/55	19:59	:01	1	(1) Punch "3" tape jammed.	:00	1:34	0
5/19/55	20:00	:00	0		:00	1:11	0
5/20/55	18:31	1:29	5	(1) Two different results from same tapes. (2) Person touched a circuit. (3) Reader "B" error. (4) Light on reader "B" went out. (5) 2^{-2} error indicated.	:00	2:01	0
5/23/55	18:27	1:33	4	(1) Punch "3" tape jammed. (2) Punch "3" not punching "8" hole clean. (3) Punch "3" not punching "8" hole (Leapfrog). (4) University power failure (Leapfrog).	:00	1:38	2
5/24/55	20:00	:00	0		:00	1:41	0
5/25/55	19:03	:57	3	(1) Two different results from same tapes. (2) Reader B or punch "3" error on Leapfrog. (3) Punch "3", belt broke and pulley loose.	:00	4:13	1
5/26/55	19:13	:47	3	(1) Voltage on reader incorrect. (2) Punch "4" broke tape. (3) Punch "4" broke tape.	:00	1:13	0
5/27/55	19:58	:00	0		:02	1:01	0
5/31/55	19:57	:01	1	(1) Two different results from same tapes.	:02	1:18	0
	405:04	14:35	42		:21	33:34	6

running time when the machine was operating, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 6:00-6:30 P.M. period (when the machine is checked) if no errors are found, the time is given to the "running column." Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that any interruption of machine time that was not planned for is considered a failure in this table. In rare cases where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This overall system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" at any instant of time and the probability of a failure during any given interval of running time.

VI. COMMENTS ON THE ILLIAC AND RELATED FACILITIES.

New Punches

The new Teletype punches operating at 60 characters per second have been put into service.

Magnetic Drum Auxiliary Memory

Some additional tests have been carried out on eight tracks comprising 512 words on the new drum. These tests show that the frequency response of the recording and playback was such that the 80KC signal amplitude measured at the head was about 75% of the 40KC signal amplitude. In the preamplifier units the 80KC signal amplitude is reduced to about 95% of the 40KC amplitude. Partial compensation for the loss in high frequency response in the drum reading heads and preamplifiers has been introduced into the playback amplifiers.

Most of the necessary wiring has been completed for the 64 track, 4096 word memory which is to be used from June until the final drum unit with 12,800 words is available.

New Method of Multiplication

A new method of multiplication was devised suitable for the Illiac. In essence, for multiplicand x and multiplier y the method is this:

a) for $y \geq 0$, form xy

b) for $y < 0$, form $(-x)(-y)$

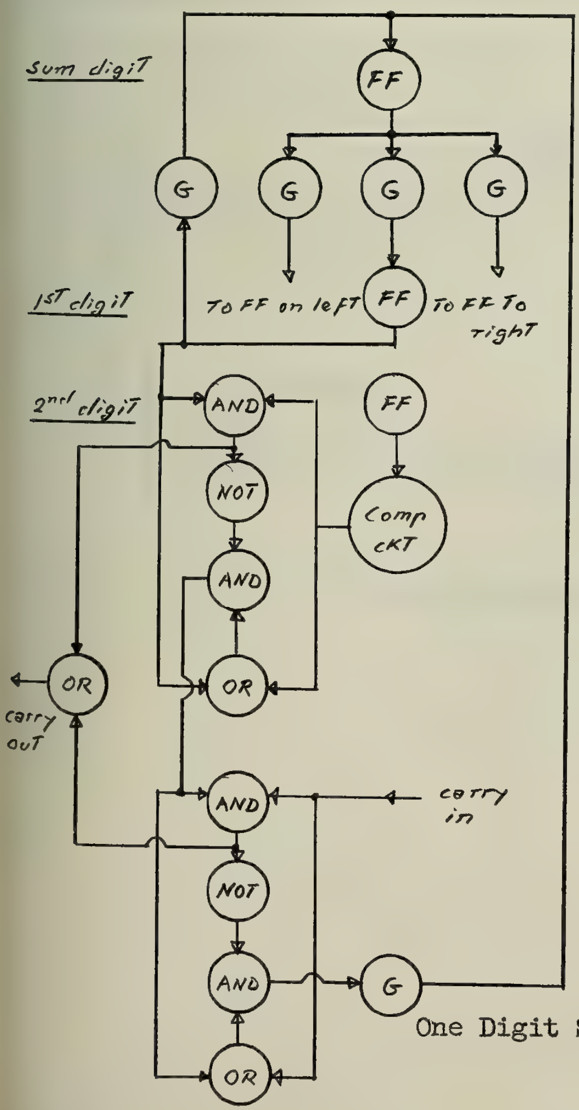
Since the digits of y are sensed serially, least significant digit first, -y can be formed by a process used in some serial computers, namely by leaving the digits of y unchanged up to and including the first 1, thereafter changing 1's to 0's and 0's to 1's. The method would eliminate the present correction circuits, but would fail if -1 were used as a multiplier. This method of multiplication has not been put into use.

VII. RESEARCH ON COMPUTER COMPONENTS.

(This work is supported in part by the Office of Naval Research under Contract N6ori-07124.)

The principal event in May was the completion of a 150-transistor 5-digit adder. Each stage is formed of a chain of logical elements as indicated in the adjoining figure. It has been found useful to have a one-to-one correspondence between the logical elements and the plug-in units. For the moment the gates and the complementing circuit have not yet been included but provision has been made for their location on the chassis.

The "and" and "or" circuits as well as the flipflops have been described previously (see the October 1954, January, 1955, and March 1955 reports). The "not" circuits have been modified in such a way that the output levels -2V and +2V are conserved for loads as low as 4K. This has been obtained

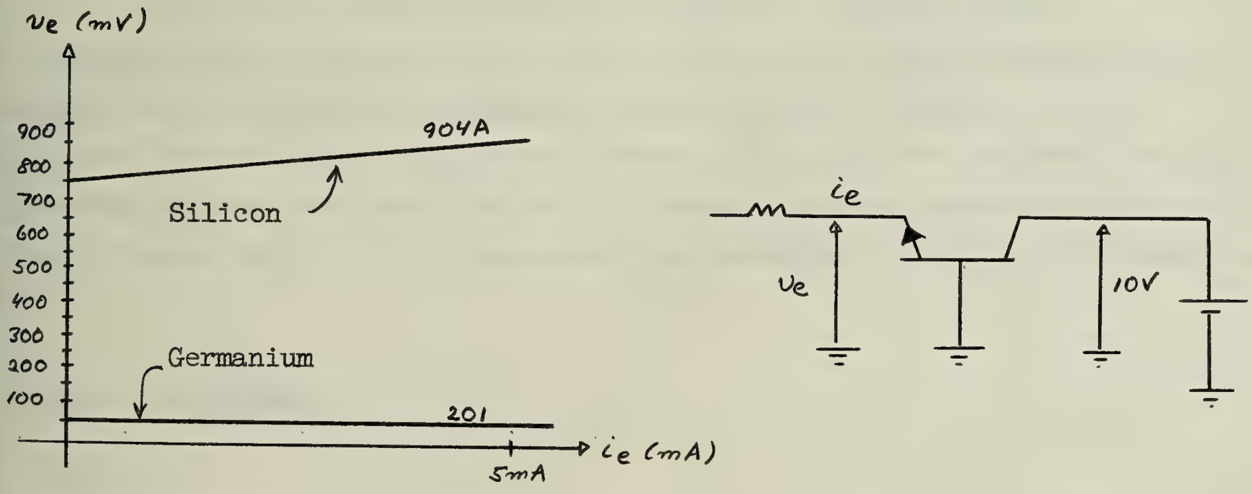


One Digit Stage of Transistorized Adder with Register Flipflops

by changing the biases on the last two emitter-followers and by using a diode across the output.

The adder, after some initial transistor failures were eliminated, gave very satisfactory results in static use: 120 hours did not produce sufficient drift to upset any of the circuits. It should be pointed out that by eliminating the gates, conditions were more severe because the output voltages of the 1/2-adders drive the flipflops directly. Tests on the dynamic behavior (carry propagate time, etc.) will be made shortly.

We finally received Si-transistors of the Type TI904A having an α-cutoff frequency of 8MC. Considerable redesigning of our circuits will have to be done if we want to use Si-devices, the reason being the large (and somewhat variable) voltage drop across the emitter-base junction. The graph below shows the input characteristic of a silicon 904A transistor as compared to that of a germanium 201 transistor.



Input Characteristics of Silicon and Germanium Transistors

VIII. CONSTRUCTION.

Drum Unit

The cross supports and top upright supports were roughed out. The two long and one of the two short I-beams are near completion except for counterboring the transformer mounting holes, and drilling the upright mounting holes. All of the milling, however, was finished on these three I-beams. A special, split, T-handle, socket wrench was made to be used in adjusting the heads on the new drum. Several more mechanical drawings were finished. Several circuit changes were made on the drum test unit, especially in the preamplifier circuits. Also 67 cable connectors were made to connect the 64 preamplifiers to the new drum. About half of these have been completed and tested. The switch panel for the final unit has been completed. The drawing for the wooden base was finished and is now at the wood shop and should be installed in the near future.

Transistor Circuit Apparatus

Work for the transistor group consisted of making a panel for a transistorized arithmetic unit. Also the transistor aging rack has been started and about three-quarters finished. The milling of the parts for the copper socket rack has been finished and assembly of it has been started. Several multiple-gang switches were modified for this unit. The two chassis for this unit have been finished and all wired except for the transistor sockets and accompanying switches.

IX. REPORTS AND SEMINARS.

Reports

Ph.D. Thesis	- "A Numerical Solution to a Class of Sturm-Liouville Equations" by Robert T. Gregory
Paper	- "Illiac Design Techniques" by James E. Robertson, presented at University of Michigan, May 25, 1955.

Seminars

"On the Interpolation of Tabulated Functions Through Exponential Sums and on the Determination of Eigenvalues from Schwartz' Constants," by Gene H. Golub, May 4, 1955.

"Oriented Graphs and Sequential Machines," by Professor Franz E. Hohn, May 11, 1955.

"Improved Methods for the Iterative Approximation of the Roots of Algebraic Equations," by Werner L. Frank, May 25, 1955.

Professor E. Stiefel, Director of the Applied Mathematics Institute, Swiss Federal Institute of Technology, Zurich, presented a series of three one-hour lectures:

1) On Solving Well-Conditioned Linear Equations Using the Theory or Orthogonal Polynomials," May 31, 1955.
2) On Solving Ill-Conditioned Linear Equations; Methods of Best Strategy," June 1, 1955.
3) Applications to Fredholm Integral-Equations and Conformal Mapping," June 2, 1955.

X. PERSONNEL.

The personnel associated with the group and hence the contributors to this report are:

Allen, Guy, Computer Operator I
Breed, Charles P., Draftsman
Carter, Clifford E., Electronics Engineer for Illiac
Clark, Miss Helen B., Secretary I
Clements, Virgil F., Jr. Laboratory Mechanic
Cole, Douglas, 1/2 time Visiting Asst. Prof. of E.E.
Douglas, A. S., Visiting Asst. Prof. of Mathematics
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Farrington, Carl C., 1/2 time Research Assistant
Fetzner, Mrs. Muriel P., Computer Teletype Operator
Fishel, Jerome H., 1/2 time Research Assistant
Frank, Werner L., 1/2 time Research Assistant
Germaine, Jack H., Jr. Electronics Technician
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Gregory, Robert T., 1/2 time Research Assistant

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Kerkering, Thomas E., Sr. Laboratory Mechanic
Lopeman, Harold E., Electronics Engineer for Illiac
McGinnis, Gerald A., Sr. Electronics Technician
Meagher, R. E., Chief Engineer
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Miller, Raymond E., 1/2 time Research Assistant
Muller, David E., Res. Asst. Prof. of Applied Math.
Nash, J. P., Res. Prof. of Applied Math.
Newmark, N. M., Chairman, Executive Committee
Ogata, Albert I., Student Assistant
Pelg, Edmund, Jr. Electronics Technician
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Russell, Miss Ramona J., Computer Operator I
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Seshu, Mrs. Lily H., 1/2 time Research Assistant
Stephens, Allen, Jr. Laboratory Mechanic
Taub, A. H., Res. Prof. of Applied Math.
Wenta, Joseph, Sr. Electronics Technician
Wier, Joseph M., Research Associate (3/4 time)
Yii, Roland H.C., 1/2 time Research Assistant
Yu, Hwa-Nien, 1/2 time Research Assistant

The work of the group is under the administration of an Executive Committee with the following members: N. M. Newmark, Chairman, D. E. Muller, J. E. Robertson, A. S. Douglas, J. P. Nash, A. H. Taub, and R. E. Meagher.

R. E. Meagher
R. E. Meagher

REM/hc

UNIVERSITY OF ILLINOIS
GRADUATE COLLEGE
DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

Teaching and graduate research are
not, in general, reported herein.

June 1 - June 30, 1955

I. MATHEMATICAL RESEARCH AND PROGRAMMING. (This work is supported in part by the Office of Naval Research under Contract N6ori-07130.)

Boolean Algebra

The study of the theory of asynchronous circuits was continued, leading to a more rigorous formulation of the theory and to a number of new theorems.

Random Numbers

An analysis was successfully completed of the length of the sequence of integers modulo 2^{40} obtained by a rule of the form

$$A_{n+q} = \sum_{k=1}^{q} a_k A_{n+q-k}$$

where the a_k are integers and a_q is odd. The result is of interest in as much as such a sequence was proposed as a source of pseudo-random digits. The numbers in the sequence were found to be unsatisfactory pseudo-random numbers.

A report is now being prepared which includes results of tests on a method which generates a sequence of numbers which is known to be at least 10 million numbers long at the rate of 0.6 millisecond per number. The results of tests applied to this sequence were satisfactory.

Matrix Operations

A routine has been prepared for multiplication of a matrix or its transpose by a vector, taking advantage of the zero elements of the matrix. In conjunction with this there is also an input routine which reads a matrix punched on tape and stores it (marking the zero elements) in a form for multiplication. These routines are steps toward the solution of a set of simultaneous linear algebraic equations.

Solution of Algebraic Equations

Further investigations were made of the formulas developed by Maehly. A second one was programmed but results were not as good as expected.

A comparison test was made, counting the iterations needed by Library Routine J 1 and by the method of LaGuerre. It was found that J 1 requires about

twice as many iterations as the LaGuerre method. A set of polynomials provided by a member of the Economics Department, and which had not been solvable by J 1, were solved successfully by the other method. These polynomials were of about the 17th degree with a few high-order terms and almost no low order terms. Each had a root very close to unity.

Numerical Differentiation

The numerical differentiation routine is still in the programming stage. One program for performing this calculation was discarded in favor of a more efficient method. Originally it was planned to calculate the interpolate to depth d, then the first derivative to depth d, the second derivative to depth d, etc. This required storing the interpolate and the first, second, etc. derivatives at all intermediate depths. It is now planned to calculate the interpolate and the derivatives at the first depth (i.e., as a function of 2 mesh points.) These may then be overwritten by the interpolates and derivatives at the second depth, which in turn may be overwritten by the interpolates and derivatives at the third depth, etc.

II. ANALYTICAL PROGRAM. (This work is supported in part by National Science Foundation Grant G-1221.)

Work is in progress on an Illiac program for solving any Sturm-Liouville ordinary differential equation with homogeneous boundary conditions. The method will involve evaluating the corresponding Lagrangean integral for a set of admissible functions. These functions will be made up of polynomial arcs which are continuous and have a prescribed number of continuous derivatives at the mesh points. The resulting quadratic form in the ordinates of the function will then be minimized.

A study is underway of the nature of the solutions of the equations of pseudo-stationary flow in the neighborhood of a singular point on a shock. The singular point is such that the shock has one straight branch and one curved branch emanating from the singular point but the tangent to the shock is continuous at the singular point.

The problems connected with writing an Illiac program for the integration of the equations of stationary or pseudo-stationary flow behind a shock are being investigated. The particular form of the equations being used is that proposed by Taub in a paper entitled "Determination of Flows Behind Stationary and Pseudo-Stationary Flows" to appear in the Annals of Mathematics. The stability of these differential equations is also being studied.

III. LIBRARY ROUTINES.

During the past month the following three programs were added to the active Illiac Library. Library Routine E 3 was written by Mr. Leonard Isaacson of the Department of Chemistry and Chemical Engineering.

M 14 (180) Linear Matrix Equation Solver and General Matrix Inversion. 115 words. The program uses the method of M 13 to solve the matrix equation AX = B or to invert A. Two auxiliary routines are included to provide flexible means for handling the matrices A and B and the solution X. One can

1) successively generate A and B row by row so that the whole matrix need not be in the computer at one time, or
2) have the matrices located on the magnetic drum, in the Williams memory, or on tape.

Similarly, one can obtain successive columns of X and store them on the drum or punch them on tape so that X need not be stored in its entirety.

K 6 (185) Chi-Squared. 23 words. This program calculates s^2 given by

$$s^2 = sn \sum_{i=0}^{m-1} \frac{(p_i - f_i)^2}{p_i}$$

where s and n are parameters used for scaling. The value of s is usually 1, 10, 100 or 1000 and a logical value for n is the sample size.

E 3 (196) Integration by Simpson's Rule (Function Values). 38 words. This program requires an auxiliary routine to calculate f(x) at an odd number of points which are specified by E 3. The routine is otherwise similar to E 2 which requires a set of tabulated values of f(x).

IV. MACHINE USE.

During June the following 28 new problem specifications were presented. This list does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 589. Numbers followed by T are for thesis problems.

589 Physics. Calculation of Ion-Paths of University of Illinois Cyclotron. The calculation involves evaluating a set of formulas based upon the assumption that ions follow a circular path for small increments of path.

590 Cosmotron. Equations of Motion for a Fixed Field Alternating Gradient Synchrotron. This problem consists of solving a set of differential equations expressed as 4 simultaneous first-order equations.

591 Chemistry. Linear Programming. This program is an adaptation of Library Routine M 15 for the magnetic drum.

592 Psychology. Determination of Modification Factors. This problem requires the plotting of some 30 axes in graphs, of calculating the inverse of a 15 x 15 triangular matrix and of principle components factoring of a matrix.

593 Physics. High Energy Nucleon-Nucleon Scattering. The problem requires the solution of several second-order differential equations for various values of a number of parameters. A sixth-order iteration scheme is used.

594 Physics. Photon-Nucleon Scattering. The solution of this problem requires the integration of about 16 integrals for single photon energy.

595 Psychology. Humor Study Development. The aim of this program is to develop a new form of the Cattell Humor Test. Solution will involve the obtaining of an 81 x 81 product moment correlation matrix, the performance of a centroid factor analysis on this matrix, and the performance of a number of quartimax rotations.

596 Computer. Floating Address Routine. This program is an input routine being designed for the Illiac.

597 T Structural Research. Solution of Simultaneous Equations by Relaxation. In this problem the relaxation patterns are chosen so that for linear equations and symmetric matrices, solution will be obtained in n steps.

598 Computer. Faster Version of Library Routine N 2. This is a prospective library routine with higher speed than Library Routine N 2.

599 Computer. Generation of a Random Multivariate Normal Sample. Given a covariance matrix, this program generates a multivariate normal distribution. In order to reduce the problem to the univariate case, the covariance matrix is transformed to diagonal form. Then after generating random numbers, it is only necessary to solve a set of integrals.

600 Physics. Fate of Vacancies During Quench. The Runge-Kutta method is used to solve two simultaneous differential equations which describe the formation of di-vacancies from single vacancies and the absorption of both vacancies and di-vacancies at dislocation.

601 Chemistry. Evaluation of a Vapor Pressure Equation. A transcendental vapor pressure equation is solved by a trial and error method.

602 T Chemistry. Evaluation of Ultra-centrifuge Data. Simpson's Rule is used to perform the integrations required for this problem.

603 T Psychology. Prediction of Success in Engineering. The McQuitty Pattern Analytic Method is used to evaluate the responses of 90 students on the Kuder Preference Record.

604 Physics. Electron-Electron Scattering. This program integrates the radial Schroedinger equation using the Noumerov method.

605 Psychology. Empirical Estimation of Communalities. No exact solution is known for finding communalities in the general case, but a number of methods have been suggested. This problem compares several of these methods with the new objective procedure that was used recently with good results.

606 Institute of Communications Research. Analysis of Responses to Mental Health Questionnaire. The computer is used to calculate correlations and to do a factor analysis.

607 T Psychology. Correlation of Additives. The problem to be investigated is: Will persons with different organizations of religious attitudes have different personality traits? Use will be made of Library Routine K 2 to calculate produce moment correlations, means, standard deviations, variances and covariances.

608 Institute of Communications Research. Factoring of Evaluative Semantic Scales. A class of 34 scales was found to be homogeneous relative to a larger battery in an earlier analysis. This subset is now being subjected to a final analysis. The computation will require obtaining latent roots of a correlation matrix, factoring the matrix and rotating the factors by the quartimax method.

609 Computer. Matrix Multiplication. This is a routine for multiplying a matrix A by a vector K. The characteristic of the routine is that only non-zero elements are stored and utilized.

610 Structural Research. Natural Frequencies and Mode Shapes of a Shear Beam with Unequal Masses. The physical problem reduces to a system of second-order differential equations.

611 Institute of Communications Research. Validation of Factors of Mental Health Beliefs. The stability of an obtained factor structure dealing with opinions on mental health is being investigated by repeating the analysis on a new sample of persons.

612 Physics. Structure Coefficients for Cubic Lattices. The tabulated values are required for the evaluation of the secular equations needed to obtain the band structure of cubic structures.

613 Bureau of Educational Research. Response Sets in Forced-Choice Items. The problem being investigated is whether an individual is prone to adopt one or two patterns of associating rank with position of the statement in a set of 3 statements. The method is based on Kendall's "coefficient of concordance."

614 T Physics. π^0 Meson Counting Efficiency. This problem uses Monte Carlo methods to determine the geometrical efficiency for detecting one or both of the gamma-rays from π^0 decays.

615 T Psychology. D-Statistic. The problem requires computation of a quantity depending upon two indices and then the printing of the quantity in a triangular area.

616 Psychology. Drum Centroid Factor Analysis. This problem uses the magnetic drum for carrying out a centroid factor analysis.

Table I shows distribution of machine time for June.

TABLE I

Regular Maintenance and Illiac Engineering	58:59
Unscheduled Maintenance or Repair	25:50
Drum Engineering	50:36
Leapfrog	62:38
R.A.R.	5:55
Wasted	1:25
Demonstrations	1:12
Use by Departments	
Computer Group	17:29
Classes	1:40
Physics	82:16
Control Systems Lab.	57:02
Structural Research	3:00
Structurel Research (AF 24994)	25:25
Psychology	8:52
Psychology (AF 25726A)	16:51
Education	5:41
Electrical Engineering	17:18
Chemistry	9:19
Agriculture	20:34
Cosmotron	23:35
Indiana University	5:36
Miscellaneous	38:40
Total	338:18

V. ERROR FREQUENCY AND ANALYSIS.

The machine is normally used for "engineering" and maintenance between 8:00 A.M. and 12:00 N, and for a check of its performance between 6:00 and 6:30 P.M. of each weekday. Since the periods between 8:00 A.M. and noon, together with certain irregular periods like Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more instructive from an error analysis standpoint to look at the periods between noon and 8:00 A.M. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind, a summary table has been prepared using the period between noon and 8:00 A.M. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 6:00-6:30 P.M. period (when the machine is checked) if no errors are found, the time is given to the "running column." Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that any interruption of machine time that was not planned for is considered a failure in this table. In rare cases where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This overall system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" at any instant of time and the probability of a failure during any given interval of running time.

VI. COMMENTS ON THE ILLIAC AND RELATED FACILITIES.

Magnetic Drum Auxiliary Memory

The wiring required for the 4096 temporary drum storage unit was completed. After the wiring errors were found and eliminated, the unit was

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
6/1/55	20:00	:00	0		:00	4:28	0
6/2/55	19:53	:03	2	(1) Leapfrog. Input-Output error. (2) Brake on Reader "J" working improperly.	:04	6:35	1
6/3/55	19:57	:01	1	(1) Punch "5" punching "0"'s	:02	2:37	0
6/6/55	19:16	:42	4	(1) Reader "K" error (2) Reader "K" error. (3) Possibly Reader "K" error. (4) Possibly Reader "K" error.	:02	4:40	0
6/7/55	18:13	1:47	5	(1) Reader "J" error. (2) Reader "J" error. (3) Reader "G" error. (4) Leapfrog division failure. Would run if filaments were high. (5) Tape torn because it stuck to roller of Reader "J."	:00	1:31	1
6/8/55	19:54	:06	2	(1) Reader "G" tore tape in two. (2) Leapfrog. Special Input-Output failure.	:00	2:08	1
6/9/55	19:01	:57	2	(1) Leapfrog. Input-Output error. (2) Failed to execute 24 order when attempted. Bad 5687 in memory control V_1.	:02	2:09	2
6/10/55	18:18	1:40	3	(1) Glass broken in Reader "G." (2) Reader "F" error. (3) Leapfrog. Comparison failure. A-chassis (shift sequencing) a piece of solder causing a short.	:02	1:36	1
6/13/55	19:26	:32	2	(1) Position 5 in memory failed wholesale 1→0. Bad 6J6 and 2651 (2) Punch No. 4 not punching clear "8" holes.	:02	1:39	0
6/14/55	16:51	3:09	7	(1) Would not execute 24 order. Sensitive D-19. (2) Leapfrog. Punch No. 3 bad. (3) Reader "G" reading incorrectly. (4) Tape jammed in punch No. 3. (5) Two different results from same tapes.	:00	1:50	2

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
6/14/55 (Cont.)				(6) Brake on Reader "J" faulty. (7) Control or punch no. 3 error.			
6/15/55	18:27	1:31	4	(1) Hung up on a read-in order, while looking for trouble, started again. (2) Hung up on a read-in order. (3) Punch No. 4 error. (4) Hung up on a read-in order.	:00	1:31	0
6/16/55	14:50	5:10	2	(1) Control still causing hang-ups. Found to be short in D53. (2) Leapfrog. Twisted leads A-Q. Broken wire decoding to JD end connector grid JD46.	:00	1:15	1
6/17/55	19:24	:34	5	(1) Reader "J" error. (2) Probably Reader "J" error. (3) Probably Reader "J" error. (4) Reader "J" error. (5) Unknown.	:02	1:12	0
6/20/55	19:43	:10	3	(1) Two different results from same tapes. (2) Reader "F" error. (3) Two different results from same tapes.	:07	:48	0
6/21/55	19:55	:00	0		:05	:58	0
6/22/55	19:29	:29	2	(1) Brake on reader "J" causing trouble. (2) Light on Reader "G" burned out.	:02	:52	0
6/23/55	19:25	:35	4	(1) Punch No. 5 does not punch some holes clean (2) Punch No. 5 punches "2" instead of "K". (3) Tape wound around sprocket feed in punch No. 3. (4) +100V fuse circuit 9 blown	:00	1:05	0
6/24/55	19:57	:01	1	(1) Drum code read in improperly first time, Second time all right.	:02	:58	0
6/27/55	19:58	:02	2	(1) Punch No. 3 error. (2) Punch No. 3 punched an extra "1" hole.	:00	1:14	0

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
6/28/55	19:58	:02	2	(1) Output tape wound around sprocket feed of punch No. 5. (2) Punch No. 5 punched an extra "1" hole.	:05	1:13	0
6/29/55	20:00	:00	0		:00	1:00	0
6/30/55	19:59	:01	1	(1) Punch No. 5 error.	:00	1:16	0
Totals	421:49	17:32	54		:39	42:35	9

made available for use with the Illiac. Tube failures were initially a source of difficulty; all vacuum tubes in the unit were checked during the interval June 10-July 1. Those which failed to meet original specifications (about 35%) were replaced.

Circuits for strobing playback signals ahead of the flipflop have been installed in the playback amplifiers of the drum storage unit, with a consequent increase in gain tolerance ratio from 1.3 to 1.7.

Photoelectric Tape Comparer Unit

The photoelectric tape comparer was out of operation for about one week. This trouble was traced to faults in alignment of the sprocket hole on Reader "I." The shop corrected the misalignment by widening the sprocket hole on the reader base. During the month the comparer also would not compare tapes which looked alike at a glance. This trouble was traced to a faulty reperforator unit which had the wrong spacing of characters per inch and were also misaligned laterally. The reperforator was repaired.

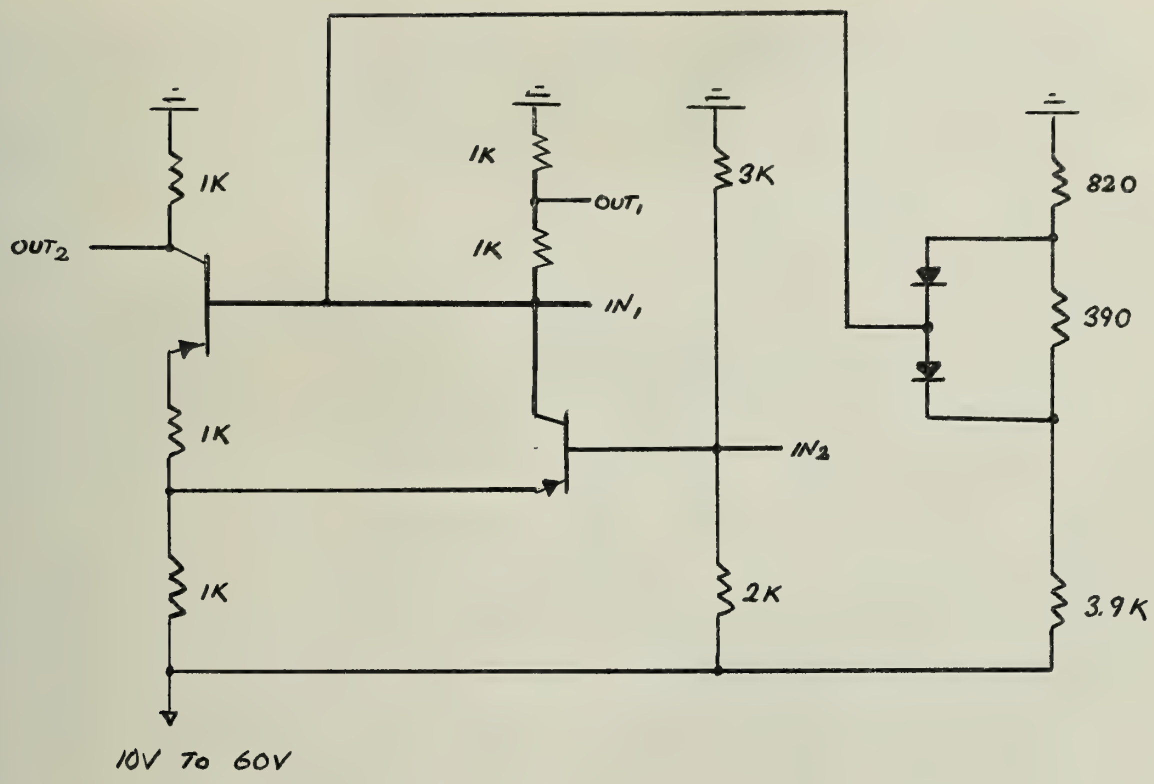
The tubes in the comparison circuit of the photoelectric tape comparer were checked. Many were low on emission. Over half the tubes were replaced. It is believed that the operating temperature is high enough to cause some of these tube failures. For this reason a room fan has been placed back of the unit and should be on whenever the unit is on. In the final installation cooling provisions should be made by having an installed blower which goes on with the ac switch.

VII. RESEARCH ON COMPUTER COMPONENTS. (This work is supported in part by the Office of Naval Research under Contract N6ori-07124.)

Direct-Coupled Transistor Circuits

The three resistor flipflop described in the May report was modified according to the adjoining figure.

1. The collector resistor of the GB amplifier is divided into two halves and an output is taken from the middle.



2. The emitter follower has a collector resistor and a second output is taken from this collector.

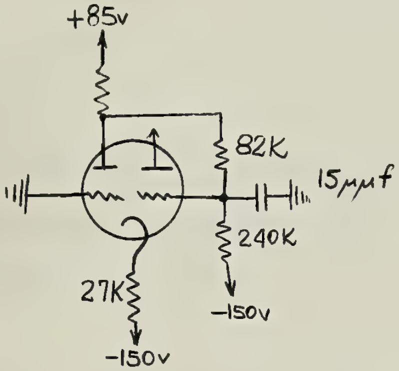
3. The base of the "GB"-amplifier is no longer directly connected to ground: This allows us to apply a trigger which is out of phase with respect to that applied ordinarily.

The result of all this is a flipflop with two out of phase inputs and two out of phase outputs. The latter have approximately the same impedance, the same quiescent voltage and the same voltage swing. The speed is of the same order as before ($< 0.5\mu s$), but the tolerance on the supply voltage is considerably increased.

Fast Vacuum Tube Circuits

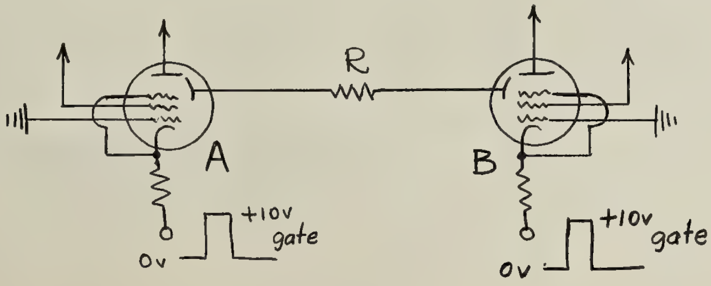
An investigation of some more types of flipflops which might be suitable for 10^{-8} second circuits led to the design of a flipflop which uses the normal type of asymmetrical tube flipflop plus a capacitor to achieve a curcuit of apparently very high speed. This is done by using the flipflop to

hold the circuit stable in a dc sense and using a capacitor to provide short time storage of the new information while the tube flipflop has time to reach its new stable state. The following circuit was tested.



Gating is intended to be done directly from one capacitor to another. Thus a gating voltage of no more than 20 volts is required at the grid, even though the plate may move much farther than that. The gating time is determined by the time necessary to change the voltage upon the capacitor by 20 volts. If the flipflop is not completely over at the end of the gate, the capacitor will hold the grid in position long enough for this to take place. As the bleeder now need not be a very low impedance circuit, the size of the capacitor may be made quite small. Thus very high speed gating is still possible. A problem does arise, however, in that small input swings do not allow for much tolerance in the design of the gating circuits. As an example, at one point in such a gating circuit it was necessary to form a positive and circuit. With the normal type logic this entails the use of diodes. In order that the capacitance that this circuit was called upon to drive could be charged by 20 volts in 10^{-8} second, a current of 40 ma. was calculated to be necessary. This means that with a maximum of 20 volts input charge, the current in one diode must change by 40 ma. Other gating circuits need to be investigated.

Another gating circuit for the secondary emission flipflops was devised. This circuit is shown below.



In order to gate from tube A to tube B, the cathode of tube B is raised enough to cut tube B off. Then, tube A will cause the dynode of B to become the same voltage as that of the dynode of tube A through the connecting resistor link. When conducting, the dynode is able to hold the set condition regardless of the state of the flipflop on the opposite end of the resistor since it will supply a negative pulling current when in the down state and a positive pulling one when in the up state. It should be stressed that this is a relatively slow gate since practically the coupling resistor must be fairly large. It also may not be used with many coupling resistors fastened to the same tube since these coupling resistors will load the circuit too much.

VIII. CONSTRUCTION.

The main work of the shop was on the final drum unit. The main frame for the drum unit was completed and set up. All detailed mechanical drawings for the frame and other structural parts have been completed.

A transistor aging rack which will permit the operation of transistors at controlled high temperatures has been completed.

The shop lathe has been cleaned and adjusted. A new head stock and tail stock have been received because the older head stock had been out of alignment with the lathe

IX. REPORTS AND SEMINARS.

Seminars

"The Calculation of the Latent Roots and Vectors of Matrices on the Pilot Model of the A.C.E.," Part I, by J. H. Fishel, June 22, 1955.

"The Calculation of the Latent Roots and Vectors of Matrices on the Pilot Model of the A.C.E.," Part II, by Lily H. Seshu, June 29, 1955.

X. PERSONNEL.

The personnel associated with the group and hence the contributors to this report are:

Allen, Guy, Computer Operator I
Breed, Charles P., Draftsman

Carter, Clifford E., Electronics Engineer for Illiac
Chow, Yuan S., Research Assistant (started June 16)
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R. E. Meagher
R. E. Meagher

REM/hc

UNIVERSITY OF ILLINOIS
GRADUATE COLLEGE
DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

Teaching and graduate research are
not, in general, reported herein.

July 1 - July 31, 1955

I. MATHEMATICAL RESEARCH AND PROGRAMMING. (This work is supported in part by the Office of Naval Research under Contract N6ori-07130.)

Roots of Polynomials

By developing a formula for the error of the method used in Library Routine J-1 it is possible to derive an expression for the order of the process as it converges to single and double roots. These orders turn out to be 1.84 and 1.23 respectively. This work has been submitted for publication.

A modification of J-1 has been made which is known to converge and which successfully finds roots of certain polynomials for which J-1 loops.

Eigenvalues and Eigenvectors

The Jacobi method for finding eigenvalues and eigenvectors of a symmetric matrix has been programmed for use with the magnetic drum. The program is an automatic one and stores as much of the matrix as possible in the electrostatic memory.

A principal objection to the Jacobi method when used with serial storage devices is that matrix elements must be treated both in rows and in columns. Thus the access time becomes very large when elements stored as rows must be read as columns. The electronic switching of tracks on the Illiac magnetic drum makes it possible to avoid this problem, for one can switch tracks in time to record or play back from the next position on any track. With 64 words per track, an element A_{jk} is stored on the drum in location $p + 65j + k$. The elements of the first row are then in locations p, $p+1$, $p+2$, ... while those of the first column are in p, $p+65$, $p+130$,.... Either rows or columns can be read with equal speed.

Magnetic Drum Programming

Work continues on programming for the magnetic drum with emphasis upon efficient recording and playback routines. One scheme uses 8-bit blocks, consisting of either function digits or address digits and stores library routines on the drum almost exactly as they appear on tape. Some saving in space over electrostatic storage is gained by taking advantage of the fact that many library routines have addresses less than 64.

Present plans call for disconnecting the record tubes and setting aside the 2560 drum locations on the first 40 tracks for permanent storage. The remaining 10,240 locations from position 2560 to position 12,799 will be generally available.

II. ANALYTICAL PROGRAM. (This work is supported in part by National Science Foundation Grant G-1221.)

Iterative formulas have been developed for generating polynomial arcs which are used to make up the admissible functions for the evaluation of the Lagrangian integral whose variation is equivalent to a Sturm-Liouville differential equation with homogeneous boundary conditions. Formulas have also been obtained for the quadratic form which results when these admissible functions are substituted into the Lagrangian integral.

In stationary flow, if a shock with a straight branch has a singular point on it then it is a simple wave in a region bounded by characteristics through the singular point and the streak line emanating from that point. A study is being made to see whether this fact can be used to determine the detailed nature of the flow in the neighborhood of such a singular point.

It has been shown that the differential equations describing the flow behind a shock as formulated in the paper "Determination of Flows Behind Pseudo-stationary and Stationary Shocks" are stable in case the flow behind the shock is supersonic.

The Einstein field equations for the gravitational field determined by a perfect fluid have been investigated for the case where all quantities exhibit plane symmetry. Static solutions have been found for a variety of cases and in this case a computational procedure has been developed for determining the gravitational field for a fluid having an arbitrary caloric equation of state. A special class of non-static isotropic flows and the gravitational fields they generate have been determined.

III. LIBRARY ROUTINES.

During the past month the following two programs were added to the Illiac Auxiliary Library. Both of these programs were prepared by Mr. R. J. Twery of the Department of Psychology.

M 16 (187) Matrix Multiplication When the Common Dimension is Large. Complete Program. This program forms the product $C_{jk} = A_{jp} B_{pk}$ subject to $j + k \leq 40$ with no limit on p. The matrix elements are furnished on tape.

K 7 (188) Iterative Estimation of Communalities: Principal Axes Method of Factor Analysis. Complete Program. The program makes a principal axes factoring of the given matrix, re-estimates the communalities, substitutes the new estimates for the old, and prepares for another principal axes factoring. The largest matrix for which this program can be used is of order 18. For such a matrix each iteration takes about 5 minutes.

IV. MACHINE USE.

During July 27 new problem specifications were presented. This list does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 617. Numbers followed by T are for thesis problems.

617 Structural Research. Elastic Arch. This is an auxiliary routine prepared for solving the equations of equilibrium of an elastic arch. It is used in conjunction with two other routines to find buckling loads and with a third routine to find static deflections.

618 Chemistry and Chemical Engineering. Calculation of Eigenvalues of Mathieu's Equation. This problem will be solved by using multiple precision floating point techniques.

619 T Chemistry and Chemical Engineering. Calculation of Hot Wire Anemometer Data. The calculations are concerned with reduction of data from anemometers

being used to measure velocity profiles, turbulence levels, and turbulent shear stress in a spiral flow field.

620 T Psychology. Analysis of Perception Tests. The problem is concerned with giving subjects two kinds of tests and then predicting from the tests of perception of physical objects to tests of perceptions of persons. Computations are done using Library Routine K-2 for determination of product moment correlations, means, standard deviations, variances, and co-variances.

621 T Physics. Change in Length of Copper, Silver, and Gold upon Irradiation. The problem is concerned with calibrating thermocouples against a platinum resistor by using an equation for expressing the relationship between resistors and temperature.

622 T Economics. Statistical Analysis of the Demand for Coffee in the United States. The analysis will be carried out largely through the use of Library Routines K-2, M-6, and M-5.

623 T Marketing. Demand for Aluminum. Through statistical analysis, the problem will study separately the demand for total aluminum and the demand for aluminum for civilian consumption. Computations will be carried out through least squares fitting and by using Library Routines K-2 and K-5.

624 Mechanical Engineering. Temperature Rise in Snow-melting Panels. This analysis is concerned with the effects of coil spacing and depth of coils and insulation under the slab on the rate of heating snow-melting panels.

625 Mechanical Engineering. Computation of a Weight Flow Table. From an equation relating the mass rate flow, Mach number and other thermodynamic properties, a table will be prepared relating weight flow and Mach numbers.

626 T Electrical Engineering. Calculation of Describing Function. Library Routine V-4 is used to perform a Fourier analysis in connection with the study of quasi-linear feedback control systems.

627 Digital Computer. Numerical Differentiation. This problem is in connection with testing a library routine.

628 T Institute of Communications Research. Use of Semantic Differential with Three Cultures in Native and English Languages. The problem is to see whether the semantic structure which ensues for three language groups is similar.

629 Dairy Science. Metabolism Study. A regression analysis will be carried out.

630 Structural Research. Deflection of a Non-linear System with Variable Coefficients. The problem requires solution of a second order differential equation and uses a method due to Newmark.

631 Bureau of Educational Research. Inter-item Correlations of California F-scale. Library Routine K-2 is the basic program and is used to evaluate results obtained from a sample of 118 education students.

632 T Structural Research. Solution of Three Concentric Spheres under External Pressure. The problem is concerned with determination of strains in a buried structure due to loads superimposed on the surrounding media.

633 Physics. Meson-nucleon Scattering. An iteration method is used to solve the equations.

634 Cosmotron. Calculation of Potential. The problem is to find out what pole faces in an accelerator will produce a desired straight-line potential and gradient midway between the magnets.

635 Institute of Communications Research. News Interest of Headlines. A Q-technique factor analysis will be made to make a statistical study of data obtained when 90 persons were asked to rate 50 headlines in order of their interest value.

636 Digital Computer. Jacobi Method for Drum. This is a test of a library program which uses the Jacobi method for calculating eigenvalues and eigenvectors of a symmetric matrix and which will make use of the magnetic drum.

637 T Electrical Engineering. Determination of Probability of Collision in Nitrogen. The problem is concerned with the solution of an integral equation.

638 Home Economics. Factors Affecting Blood Cholesterol. The Illiac will be used to investigate the interrelation of dietary factors (fat, protein, total calories) and physical measurements (blood pressure, age) with cholesterol.

639 Digital Computer. Modification of Library Routine J-1. Library Routine J-1 for finding roots of polynomials is being modified so that it will converge for some cases where it does not now converge.

640 Physics. Self-diffusion of Gold. A least squares analysis on experimental data is being carried out.

641 Cosmotron. Test Problem.

642 T Psychology. Estimation of Readibility. The calculation of variances of systematic samples of various sample sizes will be used for estimating the readibility of books as defined by the Flesch Readibility Formula.

643 Physics. Efficiency of Scintillation Counter. A Monte Carlo procedure will be used to simulate paths of electrons which have been produced by the conversion of gamma rays.

Table I shows distribution of machine time for July.

TABLE I

Regular Maintenance and Illiac Engineering	51:42
Unscheduled Maintenance or Repair	20:39
Drum Engineering	44:55
R.A.R.	5:24
Leapfrog	36:07
Wasted	1:07
Use by Departments	
Computer Group	12:56
Physics	33:44
Control Systems Laboratory	53:33
Structural Research	18:29
Structural Research (AF 24994)	19:06
Psychology	6:56
Psychology (ONR Task 35)	1:00
Psychology (AF 25726A)	24:07
Education	4:04
Electrical Engineering	10:59
Electrical Engineering (AF 310)	:17
Chemistry	29:07
Agriculture	23:36
Cosmotron	69:45
Economics	7:55
Sociology	3:34
Indiana University	1:59
Miscellaneous	7:30
Deminstrations	1:27
Total	489:58

V. ERROR FREQUENCY AND ANALYSIS.

The machine is normally used for "engineering" and maintenance between 8:00 A.M. and 12:00 N, and for a check of its performance between 6:00

and 6:30 P.M. of each weekday. Since the periods between 8:00 A.M. and noon, together with certain irregular periods like Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more instructive from an error analysis standpoint to look at the periods between noon and 8:00 A.M. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind, a summary table has been prepared using the period between noon and 8:00 A.M. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 6:00-6:30 P.M. period (when the machine is checked) if no errors are found, the time is given to the "running column." Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that any interruption of machine time that was not planned for is considered a failure in this table. In rare cases where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This overall system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" at any instant of time and the probability of a failure during any given interval of running time.

VI. COMMENTS ON THE ILLIAC AND RELATED FACILITIES.

Magnetic Drum Auxiliary Memory

The 4096 word temporary drum storage unit has continued to work well during this month. A digit-sensing and correction circuit has been added which increases the gain tolerance ratio from about 1.7 to 2.7.

A drum test code was recently added to the Engineering Code Book. Programs for the drum in the Engineering Code Book will be designated by numbers prefixed with an "S."

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
7/1/55	19:26	:34	1	(1) Light on "B" gate of Punch No. 3 went out.	None	1:06	1
7/5/55	19:29	:31	1	(1) Green gate marginal error.	None	:54	0
7/6/55	19:05	:53	2	(1) Punch No. 5 pulling sprocket holes. (2) Punch No. 3 not working properly.	:02	:58	0
7/7/55	19:39	:13	2	(1) Punch No. 3 tore tape. (2) Punch No. 5 jammed.	:08	:53	0
7/8/55	18:34	1:26	2	(1) Green gate marginal error (2) Flexible connection on Reader "I" loose.	:00	:39	0
7/11/55	18:19	1:39	4	(1) Leapfrog comparison failure. (2) Chad box overflowed; clogged chad chute of Punch No. 5. (3) Leapfrog 2^{-28} failure but not certain. (4) Leapfrog, no comment.	:02	:53	3
7/12/55	18:53	1:07	4	(1) Coupling on motor on Reader "G" broken. (2) Coupling on motor on Reader "I" broken. (3) Reader "G" error. (4) Punch No. 5 error.	None	1:40	0
7/13/55	16:34	3:25	3	(1) Leapfrog memory error $0 \rightarrow 1$ pos. 21^{-1}. (2) Punch No. 5 punching incorrectly. (3) Failure in memory position 22.	:01	:28	1
7/14/55	18:35	1:23	5	(1) Two different results from same tapes. (2) Tape jammed in Punch No. 3. (3) Light burned out on Reader "J." (4) Punch No. 5 error. (5) Punch No. 5 error.	:02	1:00	1
7/15/55	19:59	:01	1	(1) Possible Reader "G" error.	:00	1:06	0
7/18/55	19:34	:24	3	(1) Reader "G" error. (2) Failed to execute 82 order when on scope. (3) Suspect failure 2^{-4}	:02	:50	0
7/19/55	19:04	:52	2	(1) Two different results from same tapes. (2) +300 fuse in memory blew.	:04	1:01	0

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
7/20/55	18:44	1:11	1	(1) Failure on leapfrog position 2^{-4}.	:05	1:00	1
7/21/55	19:01	:57	1	(1) Leapfrog memory error 0 → 1 position 22.	:02	:52	1
7/22/55	18:44	1:12	2	(1) Printer control bad. (2) Punch No. 5 failed.	:04	1:03	0
7/25/55	19:48	:11	2	(1) Punch No. 5 failed. (2) Stopped on 82 order when on scope.	:01	2:07	0
7/26/55	19:54	:02	2	(1) Tape wound around roller of Reader "G." (2) Film jammed in cassette of scope output.	:04	:58	0
7/27/55	19:47	:09	1	(1) Punch No. 5 failed.	:04	1:21	0
7/28/55	19:56	:00	0		:04	1:09	0
7/29/55	19:53	:01	1	(1) Punch No. 3 failed.	:06	1:00	0
	382:58	16:11	40		:51	20:58	8

VII. RESEARCH ON COMPUTER COMPONENTS. (This work is supported in part by the Office of Naval Research under Contract N6ori-07124.)

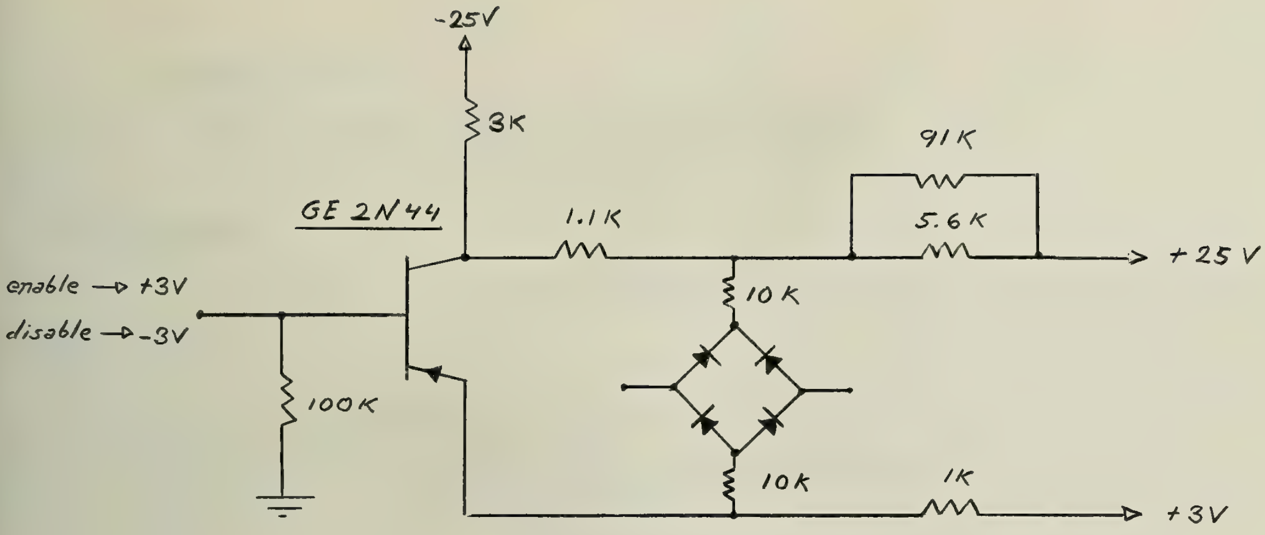
Direct-coupled Transistor Circuits

An aging rack has been constructed. This rack permits the determination of the four principal characteristics r_e, r_b, r_c and α of 60 transistors which are held at a fixed temperature in the 100-200°F range. It is constructed in such a way that any one of the transistors can be disconnected from the power supply buss lines and connected to a parameter tester, without pulling it from the socket. A group of 10 transistors of the type TI 201 have been on test for one week at 130°F, the emitter current being 1ma and the collector voltage 10v. A very considerable drop in α occurred during the first day. Instead of being in the 0.95 region, the average α went down to 0.87.

A series of experiments were conducted on GE 2N43 transistors to see if they could be run with twice the normal collector voltage, i.e. 90v. It turned out that about 50% of the units satisfied a certain selection criterion (i_{co} - increase a linear function of v_c) and then operated without any failure in a saturating pulse amplifier having 90v collector swing. This property will be extremely useful to make the neon bulb readout in transistor circuits as safe as it is in tube circuits.

An extensive program has been started to determine the α cutoff frequency and the carrier delay in transistors as a function of injection level and collector voltage. In order to make the determination of delay times more accurate than heretofore, decade delay lines have been built. The signal coming out of the transistor is then compensated by a delayed signal and fed into a scope. A wide-band scope amplifier using EFP60 tubes has been constructed.

Tests were made to see which type of gate using only one gating voltage (instead of two out of phase voltages as the standard circuit) would be acceptable for control purposes. The gate in the adjoining figure proved very satisfactory. The time to open the gate is of the order of 0.4µs while the delay time between IN and OUT is less than 0.2µs. The attenuation between IN and OUT is of the order of 0.1v, the signal levels being $\pm$2v as usual.



Gate with One Control Voltage

VIII. CONSTRUCTION.

The main work of the shop was on the final drum unit. The main frame has been completed and many of the parts for the cover frame have been completed and attached to the main frame. The mounts for the drum and additional pulser mounts were made and installed. The door hinge strips have been made.

All of the preamplifier chassis not in use have been altered to provide revised terminal wiring and a change from 6BQ7 to 2C51 tubes. The flat circuit panels for power and similar wiring have been cut and are ready for wiring. Experimental digit sensing and correction circuits were made for the drum test unit.

IX. REPORTS AND SEMINARS.

Seminars

"Preliminary Investigations on Transistorized Circuits for Driving Magnetic Core Memories," by H. N. Yu, July 13, 1955.

"Digital Techniques Applied to the Determination of Crystal Structures from X-ray Data," by Professor A. S. Douglas, July 6, 1955.

Seminars (Cont.)

"Learning Routines," by J. M. Wier, July 27, 1955.

X. PERSONNEL.

The personnel associated with the group and hence the contributors to this report are:

Allen, Guy, Computer Operator I
Breed, Charles P., Draftsman
Carter, Clifford E., Electronics Engineer for Illiac
Chow, Yuan S., Research Assistant
Clark, Miss Helen B., Secretary
Clements, Virgil F., Jr. Laboratory Mechanic
DeWit, Roland, Research Assistant
Douglas, A. S., Visiting Asst. Prof. of Mathematics
Farrington, Carl C., Research Assistant
Fetzner, Mrs. Muriel P., Computer Teletype Operator (term. July 31)
Fishel, Jerome H., Research Assistant
Frank, Werner L., Research Assistant
Gregory, Robert T., Research Associate
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Russell, Miss Ramona J., Computer Operator I
Schneberger, Edward J., Research Assistant
Seshu, Mrs. Lily H., 1/3 time Research Assistant
Stephens, Allen, Jr. Laboratory Mechanic
Suzuki, Michio, Research Associate
Taub, A. H., Res. Prof. of Applied Mathematics
Wenta, Joseph, Sr. Electronics Technician
Wier, Joseph M., Research Associate
Yii, Roland H.C., 1/2 time Research Assistant (term. July 15)
Yu, Hwa-Nien, 1/2 time Research Assistant

Student Assistants

Ciccanti, Anthony (Term. July 9)
Davenport, Mrs. Margery
Ephgrave, James T.
Geis, John P. (Started July 11)
Hill, Robert S.
Kirwan, John F. (Started July 12)
Ogata, Albert I.

The work of the group is under the administration of an Executive Committee with the following members: N. M. Newmark, Chairman, D. E. Muller, J. E. Robertson, A. S. Douglas, J. P. Nash, A. H. Taub, and R. E. Meagher.

R. E. Meagher
R. E. Meagher

REM/hc

UNIVERSITY OF ILLINOIS
GRADUATE COLLEGE
DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

Teaching and graduate research are not, in general, reported herein.

August 1 - August 31, 1955

I. MATHEMATICAL RESEARCH AND PROGRAMMING. (This work is supported in part by the Office of Naval Research under Contract N6ori-07130.)

Boolean Algebra

Calculations have been made which indicate the inefficiency of encoding information. If a word i has probability p_i and n_i digits are used for its code, then ideally $n_i = - \log_R p_i$ where R is the base of the digit system. Since n_i must be an integer, some inefficiency may be expected. An exact calculation is very difficult, but after some simplifying assumptions one obtains for the loss in digits per word encoded

$$L = \frac{\log_e \log_e R - \log_e (R - 1) - 1}{\log_e R} + \frac{R}{R - 1}$$

If we use the binary system (R = 2) this loss is surprisingly small, only 0.026 digits per word on the average. When R = 3, L = 0.05.

A method has also been devised which involves no loss due to digital coding. However the method requires an amount of calculation for encoding and decoding which is proportional to the square of the length of the message (the previous one is linear) and is therefore probably impractical even with a computer.

Numerical Quadrature

A program for evaluating definite integrals by Gauss' method has been prepared.

Linear Algebraic Equations

Investigation of indirect methods for solving systems of linear algebraic equations is being continued. The Gauss-Seidel method is being programmed, and a method of Kaczmarz will be programmed.

II. ANALYTICAL PROGRAM. (This work is supported in part by National Science Foundation Grant G-1221)

During August, work on this program consisted of preparing written reports giving results obtained to date.

III. LIBRARY ROUTINES.

The following program, prepared by Dr. George C. Stone of the Bureau of Educational Research has been added to the auxiliary library:

K-4 (171) Analysis and Intercorrelation of Scores Based on Paired Comparisons. Complete Program. The program may be used whenever N groups of raters have chosen between each of the e(e-1)/2 pairs of statements or objects formed by all possible pairings of e elements. The program will handle up to 16 elements, the number of groups which may be scored being in this case 530.

III. MACHINE USE.

During August specifications were presented for 20 new problems. This list does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 644. Numbers followed by T are for theses.

644 T Structural Research. Deflection of a Non-linear System with Variable Coefficients. The program is concerned with the solution of a second-order differential equation.

645 Structural Research. The problem is the same as 644 except for different boundary conditions.

646 T Structural Research. Three-Degrees-of-Freedom System with Complex Coupling. The program integrates three simultaneous differential equations using Newmark's method.

647 Physics. Miscellaneous Small Physics Problems. This problem specification covers small problems of two or three minutes duration for the Physics Department.

648 Chemistry. Practice Problems. Work done under this problem specification will consist of practice problems leading eventually to the programming of a random walk problem.

649 Animal Genetics. Statistical Evaluation of Experiments with Swine. This program uses Library Routine M-13 to invert matrices in the calculation of partial correlations from data obtained in experiments with swine.

650 T Structural Research. Iterative Solution of Simultaneous Equations. The problem is concerned with solutions of large sets of simultaneous equations in which the coefficients are found from some simple operations and in which most of the coefficients are zero.

651 Accountancy. Industrial Budget. This is a problem in linear programming in which, given maximum amounts of labor, capital, materials and plant capacity, it is desired to select the use of these resources to maximize profits.

652 Institute of Communications Research. Q-Techniques Methodology. Q-technique is a method used by psychologists to isolate subgroups in a collection of people on the basis of their responses on a test battery. A small problem will be analyzed using factor analysis programs from the library to enable the comparison of various methods which have been suggested for Q-technique analysis.

653 Computer. Drum Equations Test. This is a test of the solution of 96 simultaneous equations using the elimination method.

654 Mining and Metallurgical Engineering. Diffusion in Metals.

655 Mechanical Engineering. A Study of Axially Symmetric Supersonic Jet Boundaries. The problem requires the evaluation of definite integrals arising from approximations to jet boundaries.

656 Computer. Quadrature by Gauss' Method. This problem will be programmed for the library.

657 Psychology. Senate Voting Blocks. Similarity analyses will be used to group senators of previous Congresses into voting blocks on the basis of their votes.

658 Agricultural Economics. Crop Yield Variability. Multiple regression techniques will be used to find crop yield correlations for each of the five principal crops grown in Illinois over the period 1927-1954. Data from each county will be used.

659 Mathematics. Types of Magazine Audiences. Data on pairwise overlap of the audiences of 50 magazines will be analyzed by centroid factor analysis and similarity analysis.

660 UCLA. Inversion of Hilbert Matrices. The library matrix inversion routine, M-13 will be used to invert Hilbert matrices of orders 5 through 9.

661 T Physics. Meson Production by Electrons. This problem is devoted to the calculation of 3 integrals which are functions of several parameters.

662 T Structural Research. Preparation of Parameter Tapes. This is a special program for preparing coefficient tapes for Library Routine L-2. It is desired to solve several sets of simultaneous equations, one after the other in which the coefficients of one set differ from those of another by one or two numbers. This program greatly reduces the time for carrying out the computations.

663 Theoretical and Applied Mechanics. Post-Buckling Behavior of Elastic Cylindrical Shells Subjected to External Pressure. The mathematical problem here is the problem of minimizing fourth degree polynomials in seven variables. Library Routine H-6 will be used.

Table I shows distribution of machine time for August.

TABLE I

Regular Maintenance and Illiac Engineering	45:13
Unscheduled Maintenance or Repair	12:01
Drum Engineering	30:46
R.A.R.	7:17
Leapfrog	51:53
Wasted	:47

TABLE I (Cont.)

Use by Departments

Computer Group	19:21
Physics	40:31
Control Systems Laboratory	83:09
Structural Research	37:45
Struct. Res. (AF 24994)	1:52
Struct. Res. (AF 170 TEAPOT)	:56
Psychology	21:36
Psychology (AF 25726A)	17:02
Education	6:42
Electrical Engineering	10:44
Electrical Eng. (AF 310)	6:05
Chemistry	21:06
Agriculture	16:28
Cosmotron	108:19
Economics	2:46
Sociology	:39
UCLA	1:42
Miscellaneous	9:49
Demonstrations	:10
Total	554:39

IV. ERROR FREQUENCY AND ANALYSIS.

The machine is normally used for "engineering" and maintenance between 8:00 A.M. and 12:00 N, and for a check of its performance between 6:00 and 6:30 P.M. of each weekday. Since the periods between 8:00 A.M. and noon, together with certain irregular periods like Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more instructive from an error analysis standpoint to look at the periods between noon and 8:00 A.M. of the next day in order to make an observation of the error frequency in the machine.

This is the actual period when the machine is designated for use. With this in mind, a summary table has been prepared using the period between noon and 8:00 A.M. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 6:00-6:30 P.M. period (when the machine is checked) if no errors are found, the time is given to the "running column." Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that any interruption of machine time that was not planned for is considered a failure in this table. In rare cases where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This overall system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" at any instant of time and the probability of a failure during any given interval of running time.

V. COMMENTS ON THE ILLIAC AND RELATED FACILITIES.

Magnetic Drum Auxiliary Memory

During the month of August, nine errors were attributed to the drum storage unit, excluding those induced during maintenance periods. With one exception, these errors were traced to faulty vacuum tubes. The exception occurred before the head-to-drum spacing had stabilized during warmup. Tube replacements during the month were as follows:

6BQ7	23	6AL5	2
6AU6	3	815	2
6136	3	5964	1
5687	2	6J6	1

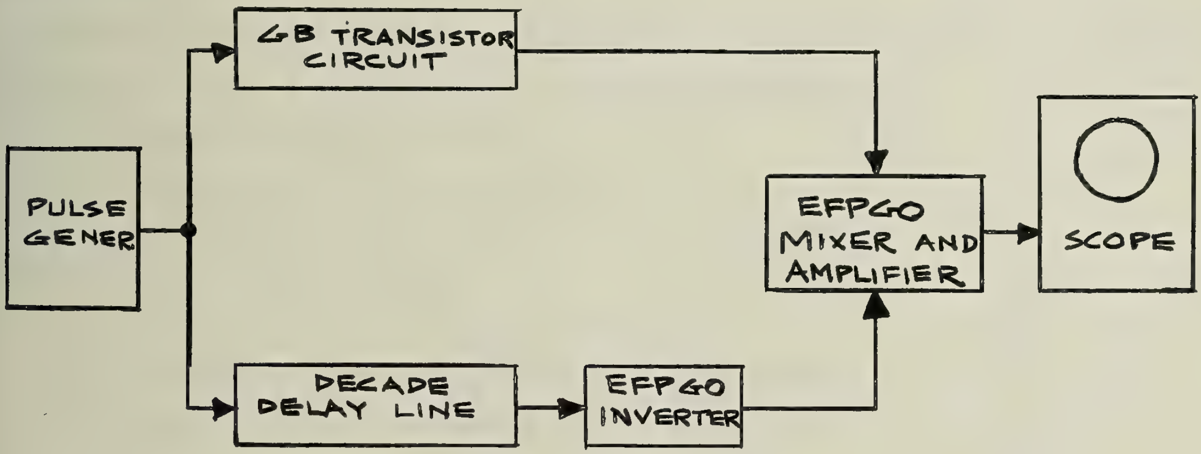
DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
8/1/55	19:51	:07	1	(1) Light on A gate burned out (Punch No. 5)	:02	:58	0
8/2/55	19:59	:01	1	(1) Reader "J" reading incorrectly (brake loose)	:00	1:26	0
8/3/55	19:31	:29	3	(1) Reader "J" error. (2) Reader "J" error. (3) Punch No. 5 jammed.	:00	:38	0
8/4/55	19:59	:01	1	(1) Possible Reader "G" error.	:00	:58	0
8/5/55	19:07	:51	4	(1) Probably Reader "J" error. (2) Probably Reader "J" error. (3) Drive Coupling on Reader "G" broke (4) Punch No. 5 error.	:02	:17	0
8/8/55	19:54	:02	2	(1) Tape broke in Punch No. 3 (possibly due to operator) (2) Error, possibly due to incorrect turning off of drum unit.	:04	1:17	0
8/9/55	16:41	3:19	3	(1) Coupling on Reader "G" loose. (2) Memory failure, position 2^{-12}. (3) Probably another memory failure 2^{-12} ?	:00	1:48	1
8/10/55	19:34	:22	2	(1) Reader "K" error. (2) Reader "J" tearing tape at brake.	:04	6:25	0
8/11/55	19:58	:02	2	(1) Reader "F" evidently read address and order pair print incorrectly. (2) Same as (1).	:00	4:30	0
8/12/55	16:28	3:30	4	(1) Two different results from same tapes. (2) Leapfrog - Input-output test. (3) Leapfrog - Input-output test. (4) Leapfrog - Memory position 2^{-15}.	:02	1:29	3
8/15/55	18:38	1:20	2	(1) Stopped on L5 (reason unknown) (2) Computer failed to execute 80 order (possibly broken or loose connection at reader cable plug)	:02	:33	0

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
8/16/55	19:21	:34	7	(1) Reader "K" error due to dirt in holes. (2) Reader "K" error due to dirt in holes. (3) Reader "K" error due to dirt in holes. (4) Clutch on Reader "G" bad. (5) Coupling on Reader "K" broken. (6) Reader "F" error. (when reader was changed the filament setting was forgotten.) (7) Stopped on L5 199. Rerun OK.	:05	:57	0
8/17/55	18:56	:58	2	(1) Tape tension in Punch No. 5 not releasing properly. (2) Leapfrog input-output test.	:06	:32	1
8/18/55	19:59	:01	1	(1) Probable Reader "J" error.	:00	1:02	0
8/19/55	19:58	:00	0		:00	1:24	0
8/22/55	19:59	:01	1	(1) Punch No. 3 jammed.	:00	1:02	0
8/23/55	19:59	:01	1	(1) Stopped on L1, reran OK.	:00	1:01	0
8/24/55	19:33	:22	4	(1) Error, type not given (2) Punch No. 3 error. (3) Brake on Reader "D" cut tape. (4) Stopped on L7 (?)	:05	:56	0
8/25/55	20:00	:00	0		:00	1:20	0
8/26/55	19:58	:02	2	(1) Punch No. 3 error. (2) Reader "G" had shorted 2C51.	:00	1:05	0
8/29/55	19:22	:38	1	(1) Number of shorted tubed in P.E. tape reader output chassis.	:00	:53	0
8/30/55	20:00	:00	0		:00	1:04	0
8/31/55	19:58	:02	1	(1) Reader "D" error. (?)	:00	1:17	0
Totals	446:43	12:43	45		:34	32:52	5

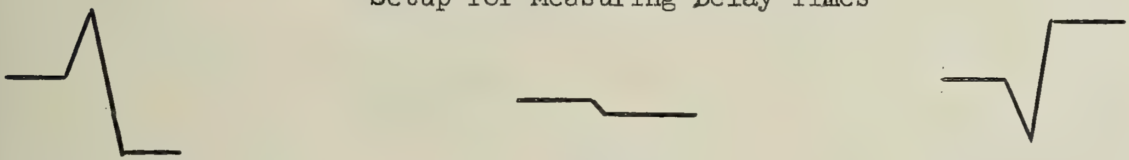
VI. RESEARCH ON COMPUTER COMPONENTS. (This work is supported in part by the Office of Naval Research under Contract N6ori-07124.)

Direct-Coupled Transistor Circuits

The study of the delay time in transistors of the type GE 2N43 as a function of current density and collector voltage has been terminated. By using a setup including a 600 ohm decade delay line with 0.01μs/section, a fairly exact picture was obtained. The adjoining graph gives (i_e) for collector voltages v_c of -30V and -5V respectively: there seems to be negligible space-charge narrowing of the base with increasing v_c, at least in the type of transistor studied. The beneficial influence of staying away from cut-off is however clearly visible.

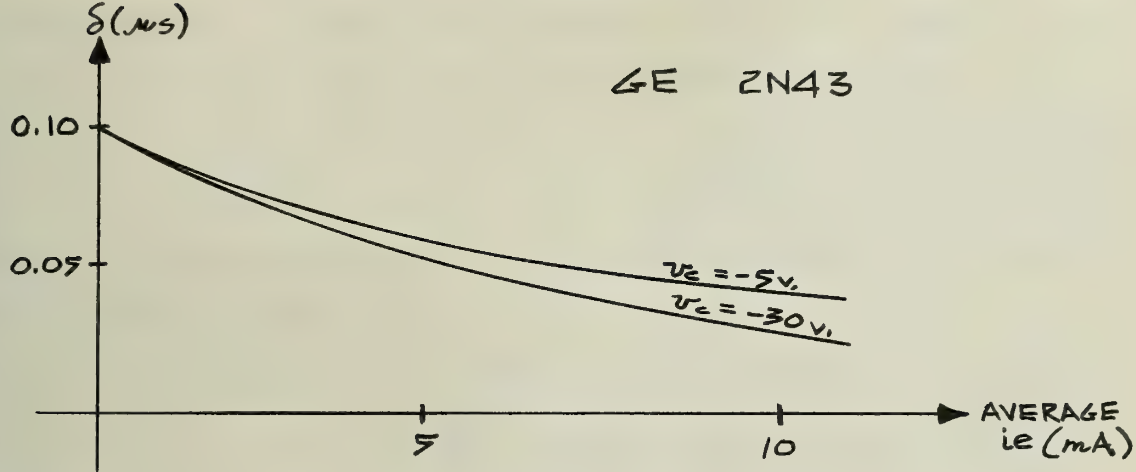


Setup for Measuring Delay Times



undercompensated   compensated   overcompensated

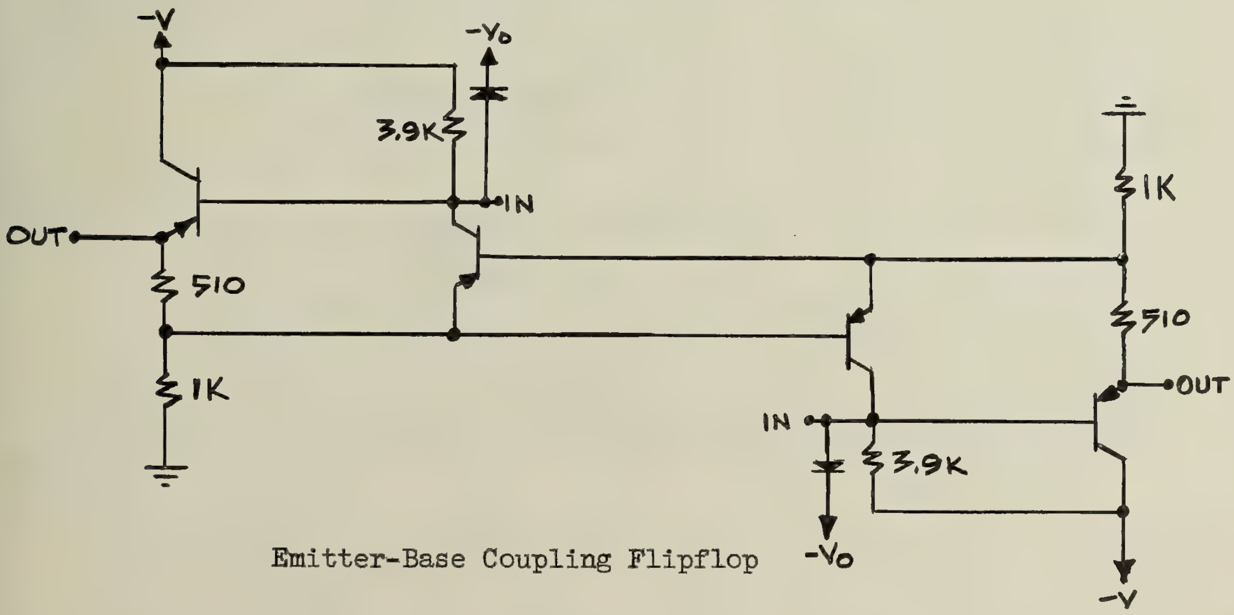
Scope Patterns for Front of Combined Pulses



Delay Time as a Function of Emitter Current and Collector Voltage

In the field of circuitry a new type of symmetric flipflop was designed which seems to have a great number of interesting properties:

1. Symmetric input and output
2. Good input/output impedance ratio (8:1)
3. Very high tolerance: 50% on resistors: more on the supply voltage
4. Uses transistors of one kind only
5. Intrinsically fast (0.2μs to last moving point using junction transistors of α cut-off 2mc)
6. Possibility of very simple gating

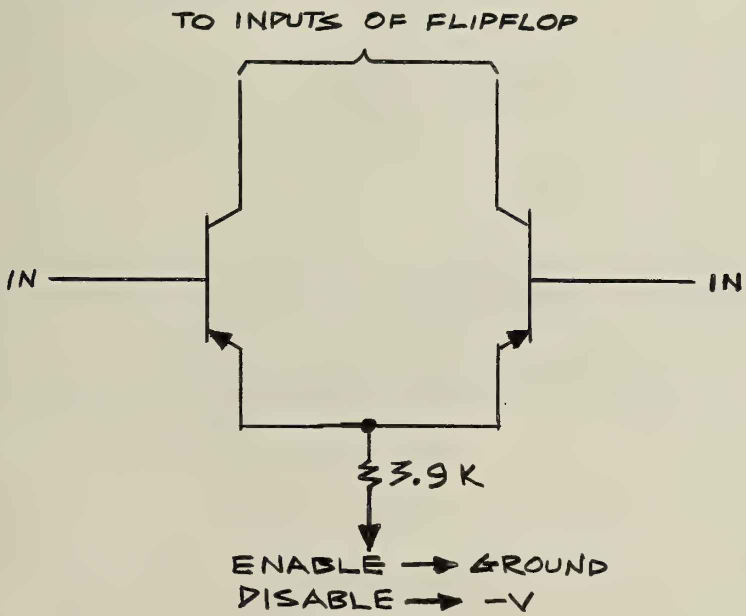


Emitter-Base Coupling Flipflop

The flipflop (see figure) is essentially the combination of two emitter-follower-GB amplifier circuits of the "3 resistor type" (see technical progress report April 1955) with a novel cross-coupling between the emitters and bases of the GB-stages. As can easily be seen, the two center transistors cannot be on at the same time, because the sum of all voltage drops in the emitter-base loop must be zero. It will be noted that the center transistors are no longer rigorously in a GB-connection, since the two base leads differ in potential by the emitter drop, i.e. 50mv.

It should be noticed that the transistors are driven into the cut-off region which, as stated above, causes additional delay. The other advantages of this type of flipflop are so great, that one might be willing to live with this additional delay.

For the transfer between registers (not involving logical circuitry) a very simple gate of the Illiac type can be used. This gate (see figure) uses the swing available at the emitter of the center transistors: this swing is low but the impedance level is very low too.



Gate for the Emitter-Base Coupling Flipflop

An analysis for tolerance and stability of the new circuits is being worked out.

VII. CONSTRUCTION.

Except for the repair and improving of six of the readers, all the work in the shops was on the final and test drum units.

All the cover panels were fitted and installed except for the two main panels on the ends and all the filament panels. The filament panels will have to be fitted after the unit is mounted on the wooden base in the Computer Room.

The following chassis work was completed or started: The matrix amplifier B, Dwg. 650, was remodeled. Matrix amplifier A was started. New chassis for Dwgs. 652 and 472 were made and assembled. The sensing and correcting circuit, Dwg. 652, has been partially wired but not completed. The register inverter chassis, Dwg. 534, and the primary matrix chassis, Dwg. 471, were completed. The wiring of the gating control chassis, Dwg. 478, was started. The dc filter panel, Dwg. 587G, was completed and wired.

VIII. REPORTS AND SEMINARS.

Seminars

"A Drum Digit Sensing and Correction Scheme," by Raymond E. Miller, August 3, 1955.

Reports

Internal Report No. 64, "Fundamentals of Junction Transistor Physics," by W. J. Poppelbaum, August 30, 1955.

Internal Report No. 65, "Some Direct-Coupled Computer Circuits Utilizing NPN and PNP Transistors in Combination," by J. M. Wier, August 31, 1955.

IX. PERSONNEL.

The personnel associated with the group and hence the contributors to this report are:

Allen, Guy, Computer Operator I (Term. 8/19/55)
Breed, Charles P., Draftsman (Term. 8/11/55)
Carter, Clifford E., Electronics Engineer for Illiac
Chow, Yuan S., Research Assistant (Term. 8/15/55)

Clark, Miss Helen B., Secretary
Clements, Virgil F., Jr. Laboratory Mechanic
DeWit, Roland, Research Assistant
Douglas, A. S., Visiting Asst. Prof. of Math. (Term. 8/31/55)
Ehmen, Mrs. M. Gwendolyn, Computer Teletype Operator (Started 8/30/55)
Farrington, Carl C., Research Assistant
Fishel, Jerome H., Research Assistant
Frank, Werner L., Research Assistant (Term. 8/31/55)
Gregory, Robert T., Research Associate (Term. 8/31/55)
Holm, Walter H., Jr. Electronics Technician
Huffman, Wm. L., Computer Operator II
Kerkering, Thomas E., Sr. Laboratory Mechanic
Lopeman, Harold E., Electronics Engineer for Illiac
Marlowe,Arnold L., Computer Operator (Started 8/15/55)
McGinnis, Gerald A., Sr. Electronics Technician for Illiac
Meagher, R. E., Chief Engineer
Michael, George W., Adminisrative Assistant
Miller, Raymond E., 1/2 time Research Assistant
Morrill, Ronald F., Draftsman (Started 8/1/55)
Muller, David E., Res. Asst. Prof. of Applied Math.
Nash, J. P., Res. Prof. of Applied Math.
Newmark, N. M., Chairman, Executive Committee
Pelg, Edmund, Jr. Electronics Technician
Polivka, Raymond P., Research Assistant (Term. 8/23/55)
Poppelbaum, W. J., Research Associate
Robertson, James E., Res. Asst. Prof. of Elec. Eng.
Russell, Miss Ramona J., Computer Operator I
Schneberger, Edward J., Research Assistant
Seshu, Mrs. Lily H., 1/3 time Research Assistant
Stephens, Allen, Jr. Laboratory Mechanic
Suzuki, Michio, Research Associate (Term. 8/15/55)
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Ephgrave, James T. (Term. 8/23/55)
Geis, John P.
Goodman, Robert (Started 8/30/55)
Hill, Robert S.
Kirwan, John F.
Ogata, Albert I.

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TECHNICAL PROGRESS REPORT

Teaching and graduate research are
not, in general, reported herein.

September 1 - September 30, 1955

I. MATHEMATICAL RESEARCH AND PROGRAMMING. (This work is supported in part by the Office of Naval Research under Contract N6ori-07130.)

Boolean Algebra and Switching Circuits

The study of asynchronous circuits has revealed a need for more careful definitions of certain basic quantities and has led to results showing the existence of a speed-independent asynchronous circuit exhibiting the same behavior as that of a synchronous circuit.

An experimental approach toward finding transformations carrying one sequential circuit into another is being made by studying a series of examples.

Statistics Programs

A new multiple regression routine is being prepared for data analysis. This routine takes the observed data and prints an almost complete analysis.

Simultaneous Equations

The program for solving simultaneous linear algebraic equations by the Gauss-Seidel method is being made into a self-contained program.

Compiling Routines

With substantial magnetic drum storage space soon to be available, a study of compiling routines which would be useful in Illiac operation is being made.

Floating Address Program

This program will form the basis for any compiling routines prepared. It is now in the last stages of preparation, most of it having already been checked in parts.

II. ANALYTICAL PROGRAM. (This work is supported in part by National Science Foundation Grant G-1221.)

Work is in progress on the writing of a code for the integration of the equations determining the flow behind a shock, given the shock curve and the flow incident upon it. The scaling involved has been studied in detail.

Various difference equations to replace the differential equations are being considered. An investigation is being made as to the feasibility of solving the same differential equations by use of the computer with different initial conditions, namely a streak line behind the shock is prescribed.

III. PROGRAM LIBRARY.

In the past month the following five programs were added to the active library:

E-4 (193)	Numerical Differentiation with Interpolation. 103 words. This closed routine uses Neville's interpolation formula and its derivatives to find $(h^{\mu}/r!)\ f^{(r)}(x)$ for given x.
E-5 (195)	Quadrature by Gauss' Method. 18 + 2n words. This is a closed routine which uses the method of Gauss to evaluate $\sum_{i=1}^{n} a_i f(u_i) \sim \int_0^1 f(u)\, du.$ The values $f(u_i)$ must be provided with an auxiliary routine written by the user. The library copy has at the end of the tape sections containing values of u_i and a_i for each value of from 2 to 16. The choice of n is made by copying the appropriate section.
P-12 (194)	Single Column Print (Revised). 13 words. This revision of an old library routine provides a delay after carriage return so that a uniform left margin will always be assured. The number of words remains the same.

K-8 (189)

Product Moment Correlations, Variance-Covariances, Means and Standard Deviations for Use with Magnetic Drum. Entire Program. The title describes this program, which is similar to K-2. Four parameters are used to specify the number of decimals for printing the correlation matrix, the variance matrix, the means and standard deviations and for the sample size. Assuming a use of D magnetic drum locations, the maximum number n of variables permitted must satisfy the inequality

$$n(n + 7)/2 \leq D + 754.$$

Y-1 (199)

Transfer Blocks of Words from Memory to Drum or from Drum to Memory. 40 words. This is a closed routine with 3 program parameters n, q and r which specify the transfer of a block of r words beginning at Williams memory location n and magnetic drum location q. The method of entry to Y-1 determines whether the transfer is to or from the drum. On transfer to the drum a sum-check constant is placed in location q + r; agreement with this constant is required on playback when a new sum is computed. Record time is 10 + 1.8r milliseconds while playback time is 10 + 1.3r milliseconds.

The following three programs were added to the auxiliary library, K-7 and M-16 being programmed by Mr. R. J. Twery of the Department of Psychology.

K-7 (188)

Iterative Estimation of Communalities: Principal Axis Method of Factor Analysis. Complete Program. The program makes a principal axis factoring of the given matrix, substitutes the new estimates for the old, and

K-7 (188) Cont. prepares for another principal axis factoring. The latent roots and new communality estimates are punched during each iteration. The largest matrix for which this routine can be used is of order 18; the time in this case is 5 minutes per iteration.

N-9 (196) Matrix Modifying Input. 43 words + 26 words of N-2. This routine is a closed one designed to store a matrix by marking zero elements and thus increase storage capacity. The size of matrix which can be stored depends upon the number N of non-zero elements, being N+1, but the matrix may not have more than 511 columns. Non-zero elements are stored to a precision of 30 binary places.

M-16 (187) Matrix Multiplication when the Common Dimension is Large. Complete Program. This program forms the matrix product $C_{jk} = A_{jp}B_{pk}$ for $j + k \leq 40$ but with no limit on p.

Programs X-9 and X-10 have been placed in the auxiliary library, and programs A-2, N-7 and RA-2 are now obsolete.

IV. MACHINE USE.

During September specifications were presented for 17 new problems. This list does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 664. Numbers followed by T are for theses.

664 Physics. Evaluation of Diffusion Data. This program calculates diffusion coefficient, vibration factor and activation energy, given intensity of radio activity and position and several radio activity constants.

665 T Agricultural Economics. Corn Drying Costs. A multiple regression program will be used to estimate the functional relationships between total variable costs and costs of corn drying with different amounts of moisture removed.

666 Agricultural Economics. Farm Machinery Selection. This program is being used in a study of competition for capital between livestock enterprises and crop machinery. It is a linear programming problem where income is maximized over a five-year period.

667 Agricultural Economics. Local Road Costs Estimation. Multiple regression methods are used on data from 1500 Illinois townships to study maintenance and construction costs of local road systems.

668 Physics. Impurities in Semi-conductors. This program is used to tabulate an integral which is necessary in the calculation of ionized impurity scattering for semi-conductors.

669 Physics. Energy Band Structure of Metals. Two functions needed in the calculation of irregular solutions to the Coulomb radial differential equation are tabulated.

670 Structural Research. General Force-Displacement for One Equation. This program computes the resistance and permanent set of a single-degree-of-freedom system when the deflection is given.

671 Structural Research. Overturning of a One-story Structure. This problem solves the differential equation of motion which describes the overturning of a one-story structure subjected to a blast wave.

672 Physics. Impurity Scattering of Semi-conductors. The program is designed to provide nodes and extrema of wave functions obtained by integration of radial wave equation for positive energies by the Neumerov method.

673 Chemistry. Restricted Random Walk. By approximating the potential of interaction with a step function, the restricted random walk is applied to charged macromolecules.

674 Agricultural Experiment Station. Nutrition experiments with swine have led to results in which there are missing data and data with unequal statistical weights. Matrix inversion techniques are being used to analyze the data.

675 Horticulture. Relationship of Popping Expansion to Ear Factors in Illinois Popcorn. Data collected over the past 15 years on samples of Illinois popcorn will be analyzed with respect to variables such as ear length, weight of shelled corn, etc.

676 Electrical Engineering. Roots of a Polynomial. Library Routine J-1 is used to find the roots of a polynomial.

677 T Psychology. Derivation of a Measure of Conflict. The mathematical method in this problem involves computing produce moment correlations and test data obtained from 30 individuals in some 20 sessions and computing centroid factor analysis for each individual.

678 T Electrical Engineering. Prediction of Overshoot to Step Functions in Higher Order Non-linear Servos. Values of overshoot in third-order systems will be obtained by solving equations obtained from LaPlace transform methods.

679 Music. (Chem. Dept. Affiliation) Analysis of Counterpoint by Monte Carlo Method. The Cantus Fermi counterpoints will be analyzed by random number techniques starting with a single voice and ending with four voices. A 15 note scale will be used.

680 Mechanical Engineering. Calculation of Jet Boundaries. A step-by-step method is used to solve an equation for axially symmetric supersonic jet flow.

Table I shows distribution of machine time for the month of September.

TABLE I

Regular Maintenance and Illiac Engineering	34:25
Unscheduled Maintenance or Repair	4:03
Drum Engineering	57:09
R.A.R.	6:17
Leapfrog	53:47
Wasted	:07
Use by Departments	
Computer Group	2:03
Physics	79:36
Control Systems Laboratory	41:00
Structural Research	34:23
Structural Research (AF 24884)	1:51
Structural Research (AF 170 Teapot)	1:03
Psychology (AF 25726A)	3:06
Psychology	14:31
Education	:32
Electrical Engineering	8:08
Chemistry	35:18
Agriculture	6:30
Cosmotron	72:10
Economics	5:43
Institute of Communications Research	37:03
Miscellaneous	7:31
Demonstrations	2:30
Total	508:46

V. ERROR FREQUENCY AND ANALYSIS.

The machine is normally used for "engineering" and maintenance between 8:00 A.M. and 12:00 N, and for a check of its performance between 6:00 and 6:30 P.M. of each weekday. Since the periods between 8:00 A.M. and noon, together with certain irregular periods like Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more instructive from an error analysis standpoint to look at the periods between noon and 8:00 A.M. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind, a summary table has been prepared using the period between noon and 8:00 A.M. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 6:00-6:30 P.M. period (when the machine is checked) if no errors are found, the time is given to the "running column." Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that any interruption of machine time that was not planned for is considered a failure in this table. In rare cases where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This overall system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" at any instant of time and the probability of a failure during any given interval of running time.

VI. COMMENTS ON THE ILLIAC AND RELATED FACILITIES.

A summary of the errors or interruptions occurring on the machine from noon until 8:00 A.M. the next day for each working day since January 1, 1955 through September 30, 1955 is contained in Table III. This table covers a period of about 3700 hours of machine use.

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
9/1/55	20:00	:00	0		:00	1:27	0
9/2/55	19:55	:05	1	(1) Bad "1" hole in reader K	:00	4:08	0
9/6/55	19:57	:03	1	(1) Comparison Failure position 2^{-25}	:00	1:36	1
9/7/55	20:00	:00	0		:00	:55	0
9/8/55	20:00	:00	0		:00	3:57	0
9/9/55	19:45	:15	1	(1) Cathode follower in 2^{-32} R_3 had burned out filament. Associated with drum.	:00	2:02	0
9/12/55	19:58	:02	2	(1) Possible Reader "I" error (2) Reader G broke Tape	:00	:59	0
9/13/55	19:57	:03	1	(1) Punch No. 3 jammed	:00	2:00	0
9/14/55	19:30	:30	2	(1) Failed to execute 92 order, broken lead on A gate Punch 5 (2) Punch (5) tore tape.	:00	:50	0
9/15/55	19:53	:07	1	(1) Program did not go on first two attempts, third time, OK. Reader I	:00	:50	0
9/16/55	17:57	2:03	2	(1) Looped on 1st try, 2nd OK (2) Power Failure	:00	1:50	0
9/19/55	19:59	:01	1	(1) Probable reader "I" error	:00	:57	0
9/20/55	19:45	:15	1	(1) Tape wound around roller of Reader G	:00	2:40	0
9/21/55	20:00	:00	0		:00	1:20	0
9/22/55	19:59	:01	1	(1) Punch No. 5 punch 4 instead of 0	:00	1:14	0
9/23/55	20:00	:00	0		:00	3:13	0
9/26/55	20:00	:00	0		:00	3:06	0
9/27/55	19:55	:05	1	(1) Punch No. 4 jammed	:00	:55	0
9/28/55	19:59	:01	1	(1) Reader I tore tape	:00	1:30	0

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
9/29/55	19:32	:28	2	(1) Reader "I" error (2) Mult. failure. Leapfrog 2^{-2}	:00	1:00	1
9/30/55	19:58	:02	2	(1) Reader "F" tore tape (2) Reader "F" tore tape	:00	1:14	0
Totals	415:59	4:01	20		:00	39:43	2

TABLE III

SUMMARY OF ERRORS OR INTERRUPTIONS
FROM JANUARY 1, 1955 TO OCTOBER 1, 1955

MONTH	ARITHMETIC UNIT	CONTROL	READING	PUNCHING	MEMORY	UNKNOWN	POWER SUPPLIES	FILM CASSETTE JAMMED	PRINTER CONTROL
January	1	11	22	3	2	5			
February	3		14	1	6	10			
March			12	9	2	11			
April		3	12	9	9	8			
May		1	14	13	2	9	3		
June	1	10	25	12	1	5			
July		4	8	15	6	4	1	1	1
August			25	8	2	9			
September	1		11	5	2		1		
Totals	6	29	143	75	32	61	5	1	1

Total Number of Errors or Interruptions	353
Average per Month	39.22

Magnetic Drum Auxiliary Memory

A number of difficulties were encountered in the temporary drum storage unit during the month. The more serious of these were:

1) An open filament in the cathode follower attached to $2^{-32}R_3$ in the Illiac. It was observed that faults in track address digits are not caught by the drum test code.

2) An incorrect setting of a strobing level in the digit sensing and correction circuits. The error was first observed during the execution of a matrix problem (Spc. No. 608), rather than by the drum test code. It was learned that a contributing factor to the difficulty is that recording a word affects the beginning of the next word on the drum, due to overshoot of the record signals. The timing is such that the overshoot does not affect the playback signals during the strobe time. Preliminary modifications of the drum test code to detect similar difficulties have been coded and checked.

VII. RESEARCH ON COMPUTER COMPONENTS. (This work is supported in part by the Office of Naval Research under Contract N6ori-07124.)

Direct-Coupled Transistor Circuits

A 2000-hour test of 10 transistors of the type TI 201 has been terminated during the month of September. The transistors were run at a nominal temperature of $130^{\circ}F = 55^{\circ}C$, the actual temperature varying between $50^{\circ}C$ and $60^{\circ}C$. Using the collector-dissipation derating formula for germanium transistors in GB-stages, i.e.

$$\frac{P(25) - P(t)}{P(25)} = \frac{t - 25}{60}$$

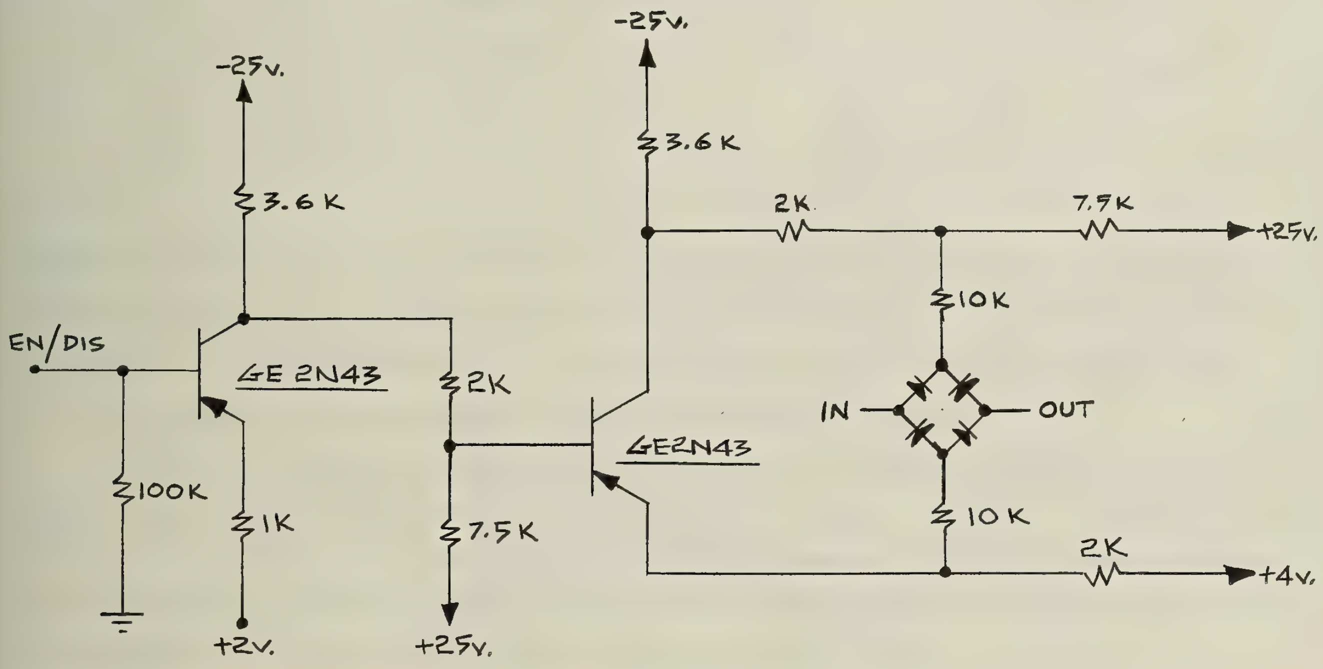
($P(t)$ = rating at temperature t), we obtain an allowable dissipation of 25 mw. We used $i_e = 1ma$, $v_c = 20v$.

All transistors showed a sharp initial drop in α: the nominal value was .95; after 4 days all the alphas were near .85. 8 of the transistors stayed in the .85 range for the rest of the test. Two however went down to .75 after 30 and 60 days respectively. The same experiment is now going to be repeated using transistors of the type GE 2N45.

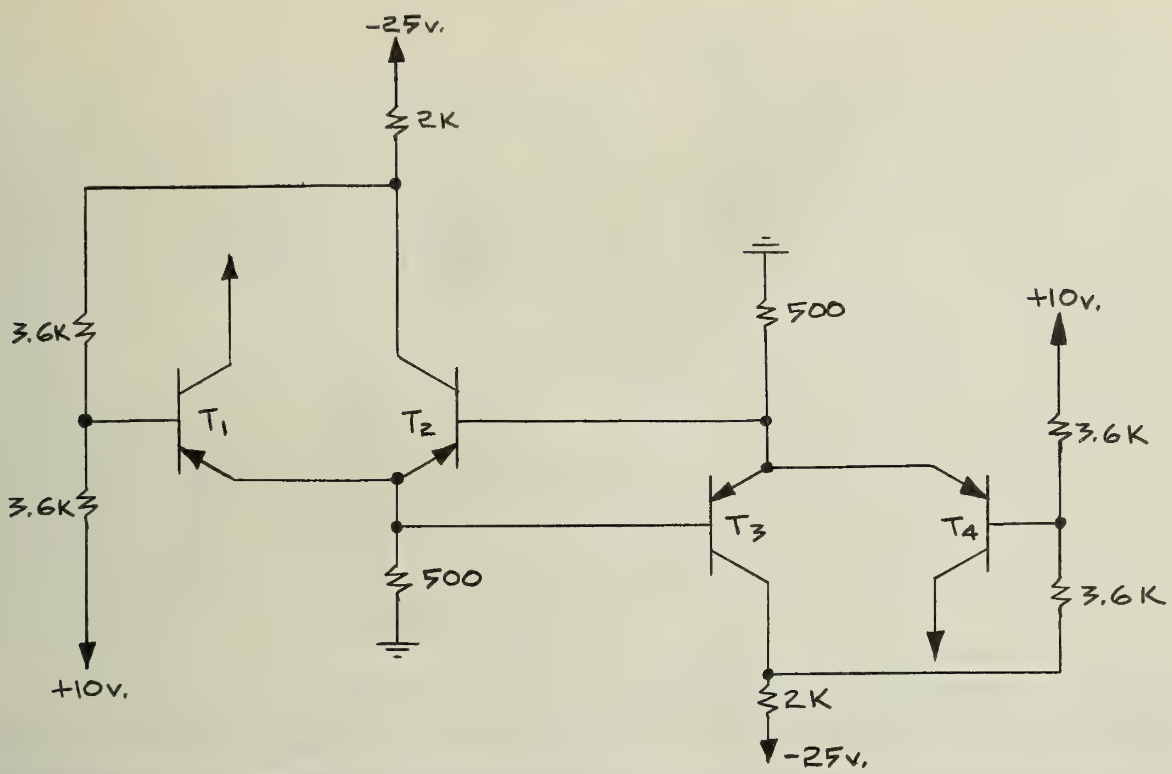
The second stage of the development of a small transistorized model computer of the simplest kind was started. Gates and complementing circuits

were put into the adder described in the May issue. The carry-propagate time for 5 stages was determined and found to be of the order of .5μs. The logical design of a control is underway and a considerable number of standard plug-in units (and, or, not and flipflops) have already been constructed.

For applications in the control circuits a new kind of gate-driver was developed which uses the old bridge-modulator gate but drives it with ±3v in spite of a control voltage of ±2v: this allows the diodes to work in the linear region, thus guaranteeing a good shape of the output signal. The figure below gives the circuit values.



The emitter-base crosscoupled flipflop mentioned in last month's report was modified in such a way as to eliminate the diodes (see figure).

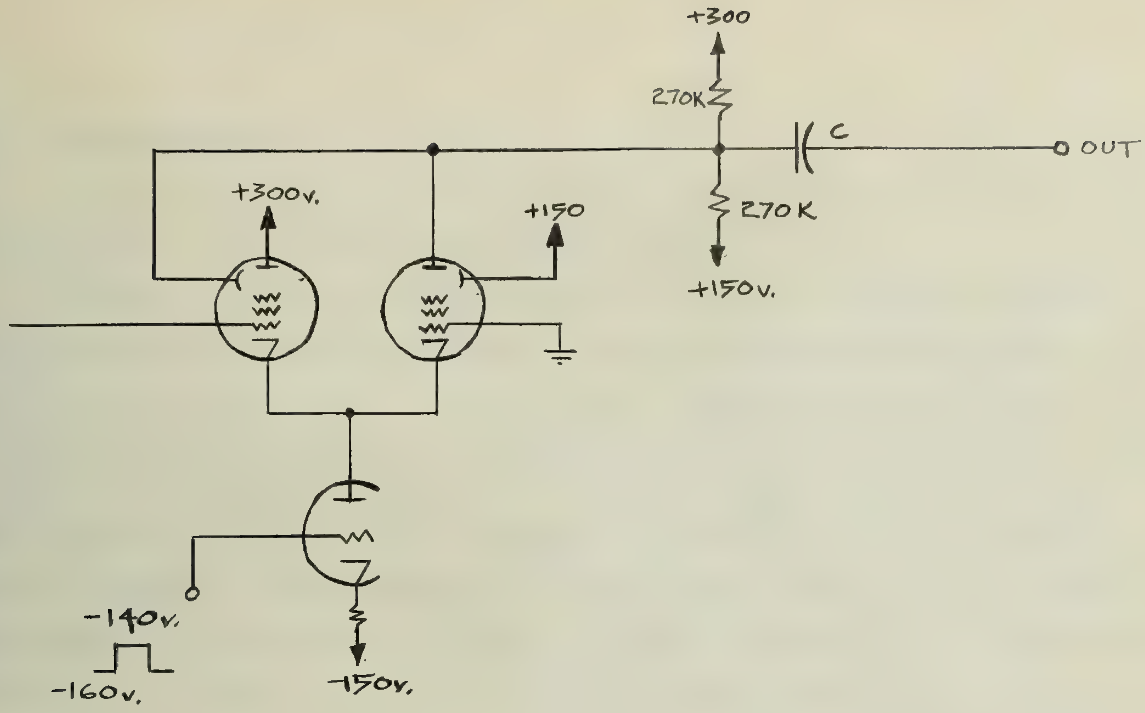


The principle is simply that when the collector of transistor T_2 for example goes too far up (i.e. towards saturation), transistor T_1 is cut off and the loop gain is reduced below 1. To achieve this result, a positive bias has to be applied to the lower end of the 3.6K voltage divider.

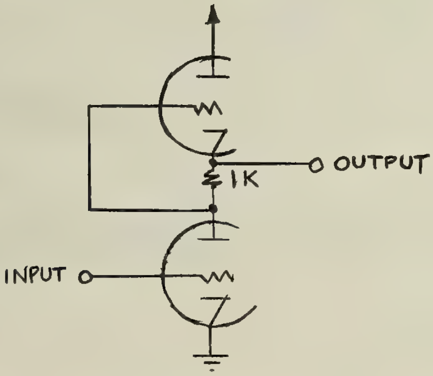
Free running registers were built using both versions of the emitter-base cross-coupled flipflop and 1858 transistors ($f_\alpha \sim 2.2$mc). In both cases times of the order of .35µs/operation were obtained. These times are approximately twice as large as those deduced from square-pulse testing; but this is a phenomenon which is encountered in tube circuitry too.

High Speed Vacuum Tube Circuits

Two schemes for coupling from a single moving point flipflop to single moving point flipflop were considered. One of these systems merely connects the output of the gate down to the single moving point through a condenser. Such a system seems reasonable so long as no more than one gate is fastened to a flipflop, assuming ac coupling is acceptable. The circuit is shown below.



The second scheme has not been successfully realized, but it seems to offer some possibilities. As yet, however, no very good way of producing the and operation necessary with a gate has been produced. The circuit is shown below.



Ir may be seen that when the lower tube is cut off, the upper tube is at 0 bias and thus pulls upward. When the lower tube is conducting, the upper tube is cut off and the lower tube pulls down on the output. The difficulty is found in putting the circuit in a state where it neither pulls up nor down while still retaining the apparent speed of operation.

VIII. CONSTRUCTION.

Except for the repair and improving of three readers, all work in the shops was on the final and test drum units.

Work on the covers was finished and the final unit was dismantled down to the main frame and moved into the Electronics Laboratory where all of the wiring will be done. All the primary filament wiring has been completed and the brackets for the secondary busses were made and put on. Most of the wiring of Dwg. L587 has been completed. Panels 587A, 587B, 587C, 587F, 587H and 587I have been completed. Also $587D_1$ has been started but not yet finished. Panel 587E has not been started. Wiring of the following new chassis was completed: CN (M472), PG (M477), GC (M478), SC (L652) and one set of 3 PU (L655). Also SMa (M648) has been remodeled.

All of the filament strips for the uprights have been laid out and half of them have been cut out. Filing and straightening of them has been started.

The following chassis still have to be remodeled. RA (M550), SMb (M647), MAa (L649), PU_3 (M653) and PA (L654). Also further changes in the PR (L626, L627, L628 and L629) are in order.

IX. REPORTS AND SEMINARS.

Seminars

"Statistics Applied to Electrons" by W. J. Poppelbaum,
September 28, 1955

X. PERSONNEL.

The personnel associated with the group and ehnce the contributors to this report are:

Bartky, Walter Scott, 1/2 time Res. Asst. (Started Sept. 16)
Carter, Clifford E., Electronics Engineer for Illiac
Clark, Miss Helen B., Secretary
Clements, Virgil F., Jr. Laboratory Mechanic
DeWit, Roland, 1/2 time Res. Asst.
Ehmen, Mrs. M. Gwendolyn, Computer Teletype Operator

Farrington, Carl C., 1/2 time Res. Asst.
Fishel, Jerome H., 1/2 time Res. Asst.
Goldberg, Jack L., 1/2 time Res. Asst. (Started Sept. 1)
Golub, Gene H., 1/2 time Res. Asst. (Started Sept. 1)
Holm, Walter H., Jr. Electronics Technician (1/2 time)
Huffman, Wm. L., Computer Operator II
Kerkering, Thomas E., Sr. Laboratory Mechanic
Lopeman, Harold E., Electronics Engineer for Illiac
Lurie, Fred M., 1/2 time Res. Asst. (Started Sept. 16)
Marlowe, Arnold L., Computer Operator I (Term. Sept. 30)
McGinnis, Gerald A., Sr. Electronics Technician for Illiac
Meagher, R. E., Chief Engineer
Metze, Gernot A., 1/2 time Res. Asst. (Started Sept. 1)
Michael, George W., Administrative Assistant
Miller, Raymond E., 1/2 time Res. Asst.
Morrill, Ronald F., Draftsman
Muller, David E., Res. Asst. Prof. of Applied Math.
Nash, J. P., Res. Prof. of Applied Math.
Nelson, James C., 1/2 time Res. Asst. (Started Sept. 1)
Newmark, N. M., Chairman, Executive Committee
Pelg, Edmund, Jr. Electronics Technician
Poppelbaum, W. J., Res. Asst. Prof.
Robertson, James E., Res. Asst. Prof. of Elec. Eng.
Russell, Miss Ramona J., Computer Operator I
Schneberger, Edward J., 1/2 time Res. Asst.
Seshu, Mrs. Lily H., 1/2 time Res. Asst.
Taub, A. H., Res. Prof. of Applied Math.
Wenta, Joseph, Sr. Electronics Technician
Wier, Joseph M., Research Associate
Yu, Hwa-Nien, 1/2 time Res. Asst.

Student Assistants

Geis, John P.
Goodman, Robert
Hill, Robert S.
Kirwan, John F.
Ogata, Albert I.

The work of the group is under the administration of an Executive Committee with the following members: N. M. Newmark, Chairman, D. E. Muller, W. J. Poppelbaum, J. E. Robertson, J. P. Nash, A. H. Taub, and R. E. Meagher.

R. E. Meagher
R. E. Meagher

REM/hc

UNIVERSITY OF ILLINOIS
GRADUATE COLLEGE
DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

Teaching and graduate research are not, in general, reported herein.

October 1 - October 31, 1955

I. MATHEMATICAL RESEARCH AND PROGRAMMING. (This work is supported in part by the Office of Naval Research under Contract N6ori-07130.)

Boolean Algebra and Switching Circuits

In the theory of asynchronous circuits the operation of a circuit may be described by listing the time relationships of various changes appearing in the circuit. These changes may be partially ordered and expressed graphically by what are called change charts. Various ways of interconnecting speed-independent circuits have been devised which preserve the property of speed independence. The change chart of the combined circuit can be represented by a merging (also of various types) of the change charts of the individual circuits.

This technique has been used to build complex speed independent circuits from simpler ones. For example, we can form a scale of pq from a scale of p and a scale of q. In a different type of interconnection we may obtain a scale of p+1 from a scale of p. More general cases than these have actually been considered. It is important to keep in mind that these scaling circuits are defined and constructed in a very different way from conventional circuits.

The object of this work is to further the development of a rigorous mathematical theory of asynchronous circuits and to develop techniques to use in designing them.

The logical design of several counters and recycling machines, some of them of the speed-independent type, has been completed. The study of a speed-independent Gray code counter with an additional binary translation property is continuing. An internal report covering speed-independent counters is being prepared.

Floating Address Program

The basic design of this program is now established and will not be changed. The section which compiles the list of floating addresses is faster and the decoding section has been speeded up.

Sturm-Liouville Systems

This research is directed toward determining the effectiveness of making a high-order polynomial approximation to the function y(x) as opposed to using a large number of mesh points in minimizing the integral

$$I = \int_a^b p(x)y'^2 - q(x)y^2 - \lambda y(x)y^2 \ dx.$$

The case is being studied now for p = r = 1, q = 0. Results of this study will dictate what further work needs to be done.

Solution of Ordinary Differential Equations

A floating point version of the Runge-Kutta routine (F-1) has been prepared. This routine was found to be more efficient than an earlier version (which was never placed in the library) as well as easier to use. A final test on a large set of equations will soon be made.

Eigenvalues and Eigenvectors

A new automatic eigenvalue-eigenvector routine has been written. This routine, which makes use of the magnetic drum, will be simpler to use than Library Routine M-3 and will permit consecutive runs on different sets of matrix data.

Post Mortem Routines

The present Combined Post Mortem (Library Routine C-10) provides for the printing of groups of 10 words in any of five ways specified by the user: fractions, integers, order pairs, sexadecimal numbers, or floating point numbers. Routine C-10 first transfers the contents of electrostatic storage locations 3-1023 to the magnetic drum. The new post mortem routine will perform the functions of C-10 and it is hoped that it will also include C-1, the Post Mortem of the Decimal Order Input and C-6, the Address Search Routine. Seven options will then be possible and programmers will be able to get results easily and quickly.

II. ANALYTICAL PROGRAM. (This work is supported in part by the National Science Foundation under Grant G-1221.)

The coding of the integration of the equations determining the flow behind a shock, given the shock curve, and the flow incident upon it, is progressing. A second order integration technique is being investigated.

The coding of the same problem with different initial data, namely the prescribing of a streak line behind the shock, is also under way. Here a study is being made concerning the use of the distance along the streak line and the distance along the shock as independent variables in contrast to the characteristic variables of the problem.

III. MACHINE USE.

During October specifications were presented for 9 new problems. This list does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 681. Numbers followed by T are for theses.

681 Physics. University of Rochester. Solution of Integral Equations for Meson-Nucleon Scattering. This is a continuation of a problem begun in the Physics Department of the University of Illinois.

682 Structural Research. Dynamic Response of a Multi-Degree-of-Freedom System. The problem involves the solution of a second order differential equation.

683 Computer. Revised Automatic Eigenvalue Routine. By using the magnetic drum only two parameters are needed for calculating eigenvalues and eigenvectors of a symmetric matrix. These parameters designate whether both eigenvalues and eigenvectors are to be computed and the number of decimal places to be printed. Problems can be run consecutively.

684 Dairy Science. Prediction of Milk and Fat Production from Physical Measurements of Calves. The data gathered will be processed using Library Routine K-2.

685 Electrical Engineering. Test Problem for Bessel Function Calculation. The program calculates $J_0(x)$ using a power series representation.

686 Industrial Education. Training Needs Test Analysis. The Training Needs Test consists of 18 test scores and a total score. Three problems to be solved are the matrix of intercorrelation tests, the matrix of correlations of the test scores and total score with the criterion measures, and the split-half reliability coefficient for each of the sub-tests.

687 Dairy Science. Measurement of Genetic and Environmental Changes in a Herd of Cattle. The problem is carried out by the solution of simultaneous linear algebraic equations.

688 Electrical Engineering. Calculation of Bessel Functions. Results of this calculation will be used to integrate the electrical and magnetic field equations where circular symmetry occurs.

689 T Theoretical and Applied Mechanics. Boundary Value Problem in Thin Plate Theory of Elasticity. The problem involves solutions of simultaneous linear algebraic equations.

Table I shows distribution of machine time for the month of October.

TABLE I

Regular Maintenance and Illiac Engineering	45:58
Unscheduled Maintenance or Repair	9:29
Drum Engineering	11:49
R.A.R.	5:51
Leapfrog	112:14
Wasted	:12

TABLE I (Cont.)

Use by Departments

Computer Group	1:03
Physics	74:29
Control Systems Laboratory	57:20
Structural Research Laboratory	3:27
Structural Research (AF 24994)	9:08
Structural Research (AF 170 TEAPOT)	2:25
Psychology	4:35
Psychology (AF 25726A)	1:05
Electrical Engineering (AF-310)	:08
Electrical Engineering	3:33
Chemistry	45:41
Agriculture	14:43
Cosmotron	76:31
Economics	1:37
Psychology (Navy Task 35)	:30
Institute of Communications Research	8:13
Institute of Communications Research (PH 3M9067)	:34
Classes	1:45
Demonstrations	11:20
Miscellaneous	10:18
	513:58

IV. ERROR FREQUENCY AND ANALYSIS.

The machine is normally used for "engineering" and maintenance between 8:00 A.M. and 12:00 N, and for a check of its performance between 6:00 and 6:30 P.M. of each weekday. Since the periods between 8:00 A.M. and noon, together with certain irregular periods like Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more instructive from an error analysis standpoint to look

at the periods between noon and 8:00 A.M. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind, a summary table has been prepared using the period between noon and 8:00 A.M. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 6:00-6:30 P.M. period (when the machine is checked) if no errors are found, the time is given to the "running column." Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that any interruption of machine time that was not planned for is considered a failure in this table. In rare cases where the failure is now known until a later time, it is possible that no repair period is associated with the failure. This overall system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" at any instant of time and the probability of a failure during any given interval of running time.

V. COMMENTS ON THE ILLIAC AND RELATED FACILITIES.

Table III presents a summary of errors or interruptions for October.

TABLE III

Arithmetic Unit	2	Memory	4
Control	1	Unknown	0
Reading	8	Power Supplies	0
Punching	3	Printer Control	0
		Total	18

It may be noted that out of the 21 days of Illiac operation, 10 days were without an error or interruption and of the 11 remaining days 8 days had only a few minutes of "unscheduled repair" time. This month has had an unusually low error or interruption rate.

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
10/3/55	19:41	10:17	3	(1) Comparison failure 2^{-29}. (2) Failure 2^{-29} memory. (3) Failure 2^{-29} memory.	:02	1:08	1
10/4/55	17:23	2:37	4	(1) Failure 2^{-29} memory. (2) V61 memory control short caused by piece of loose wire. (3) 4 different hangups on reading in same tape. (4) Reader "J" broke tape.	:00	1:48	1
10/5/55	19:59	:01	1	(1) Multiplication failure.	:00	4:33	1
10/6/55	20:00	:00	0		:00	5:29	0
10/7/55	19:58	:02	1	(1) $0 \rightarrow 1$ 2^{-4} arithmetic error.	:00	2:17	1
10/10/55	20:00	:00	0		:00	6:45	0
10/11/55	20:00	:00	0		:00	5:25	0
10/12/55	19:55	:01	1	(1) Punch "4" jammed.	:04	6:43	0
10/13/55	20:00	:00	0		:00	7:02	0
10/14/55	20:00	:00	0		:00	4:27	0
10/17/55	19:28	:32	2	(1) Reader "I" had bad sprocket holes. (2) Light in Reader "I" burned out.	:00	3:43	0
10/18/55	20:00	:00	0		:00	5:21	0
10/19/55	19:56	:01	1	(1) Reader "J" error; read an L twice.	:03	4:54	1
10/20/55	19:59	:01	1	(1) Possible reader error.	:00	7:04	0
10/21/55	19:59	:01	1	(1) Punch "4" making errors.	:00	2:56	0
10/24/55	19:53	:07	2	(1) Punch not advancing correctly. (2) Light on reader "J" out.	:00	2:05	0
10/25/55	19:58	:00	0		:02	4:17	0
10/26/55	20:00	:00	0		:00	1:27	0
10/27/55	20:00	:00	0		:00	:51	0

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUP-TIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
10/28/55	20:00	:00	0		:00	7:35	0
10/31/55	19:57	:03	1	(1) Input output failure - glass broken in Reader "H"	:00	5:54	1
	406:06	13:43	18		:11	91:44	6

Magnetic Drum Auxiliary Memory

The temporary drum storage unit was taken out of service on October 14 and chassis to be used in the final unit were removed. During the month, new control chassis and fourteen of the twenty preamplifier chassis were checked. Additions and corrections of the drum drawings were made to standardize nomenclature throughout the complete set of drawings.

VI. RESEARCH ON COMPUTER COMPONENTS. (This work is supported in part by the Office of Naval Research under Contract N6ori-07124.)

Fast Transistor Circuits

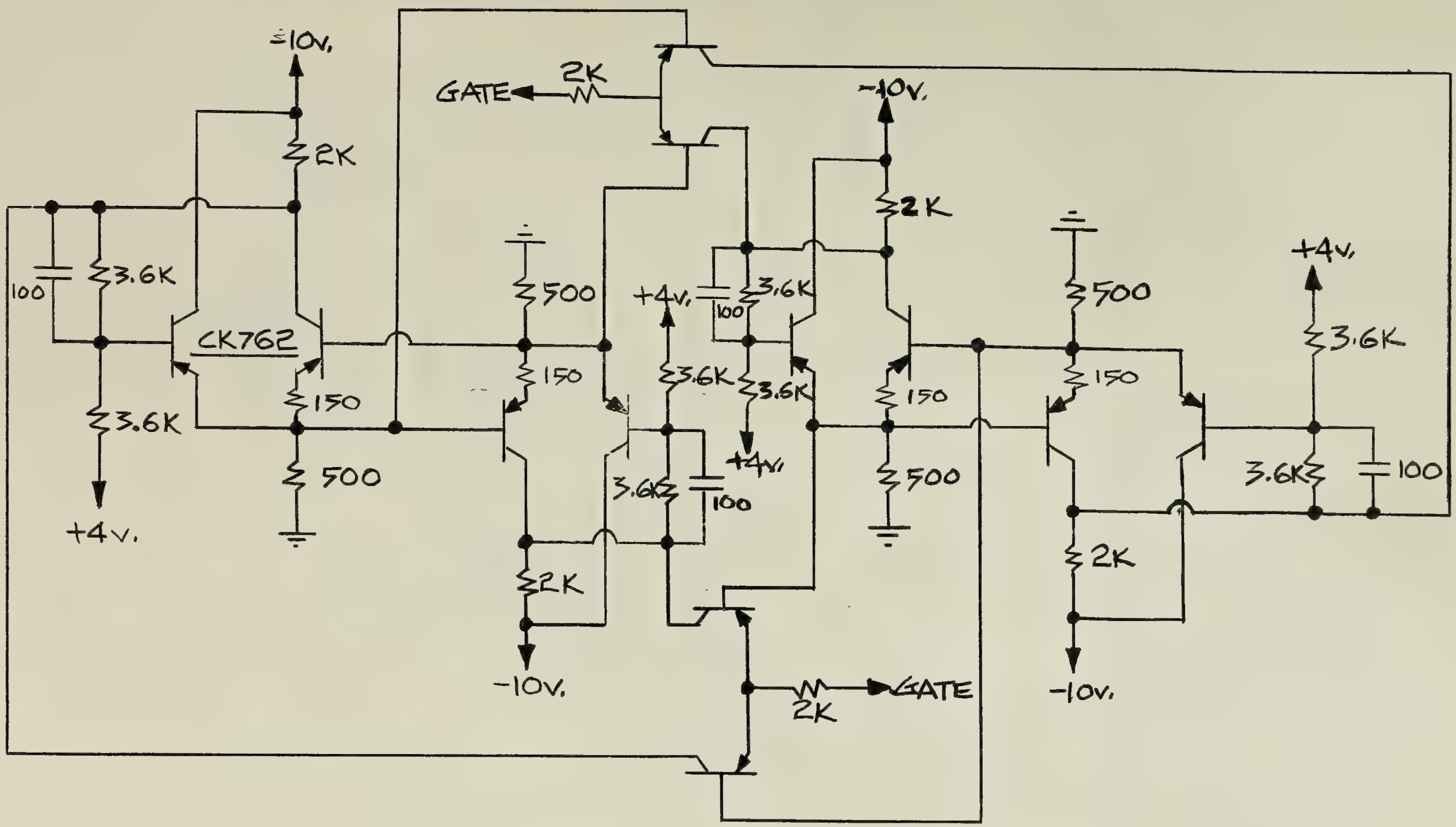
A shipment of 20 Raytheon CK762 (= 2N114) transistors had been received at the end of October. A racing register (circuit diagram on next page) was built with a speed within a factor of three of the fastest tube circuits, i.e. the combined gating and turn-over time is 90 mμs. It is interesting to compare the α-cutoff frequencies f_α of 3 kinds of transistors used in the same circuit:

Transistor	f_α	Gating and Turn-over Time
GE 2N43	1 mc	1.60 μs
WE 1858	2.2 mc	0.70 μs
Raytheon CK762	20 mc	0.09 μs

It is thought that in the near future the characteristic time for CK762 transistors can be reduced to 60 mμs: we hope to achieve this by using diode stabilization in the circuit and by lowering the impedance in accordance with the lower working voltages of Raytheon transistors.

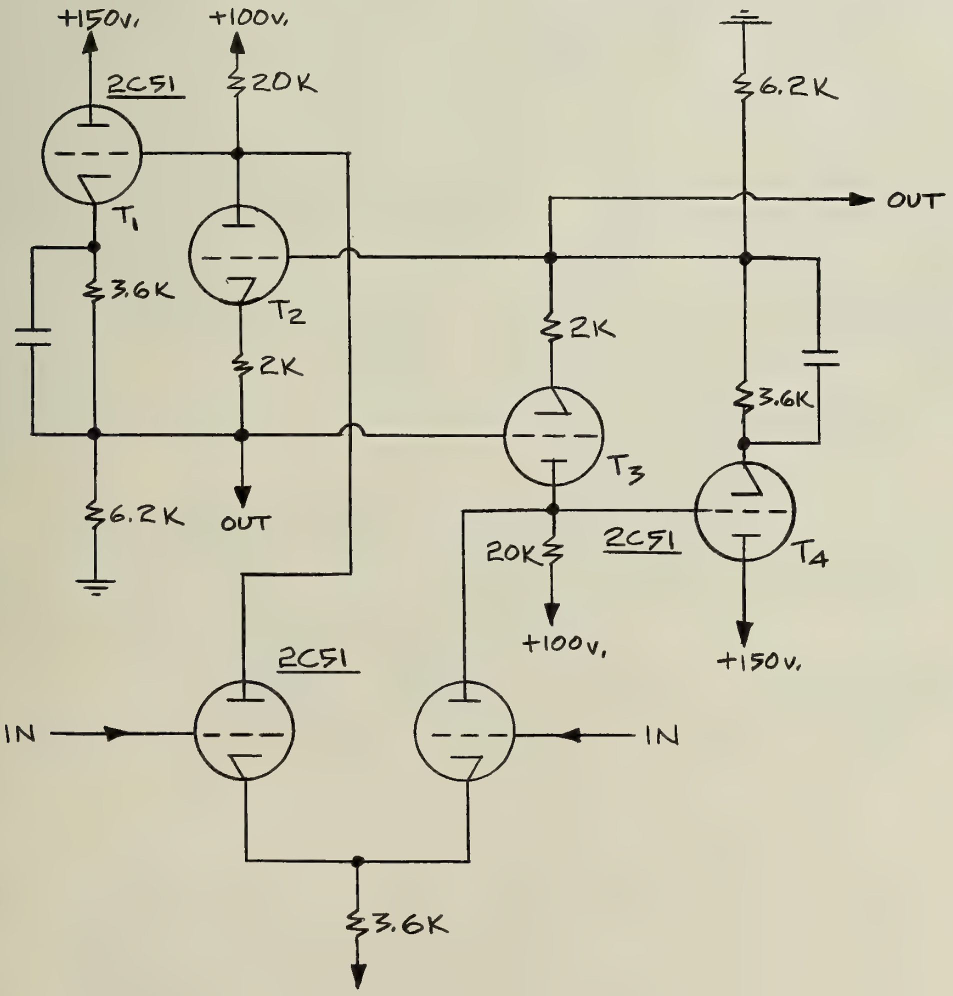
Fast Vacuum Tube Circuits

A number of new flipflop ideas were tried out experimentally and will be described in a separate report. Only two of the designs proved to be worthwhile for further consideration: one is the beam-switching tube flipflop and the other one the crosscoupled cathode-follower flipflop, a tube analog of the transistor circuit mentioned in the last section. The figures indicate how gating is performed.

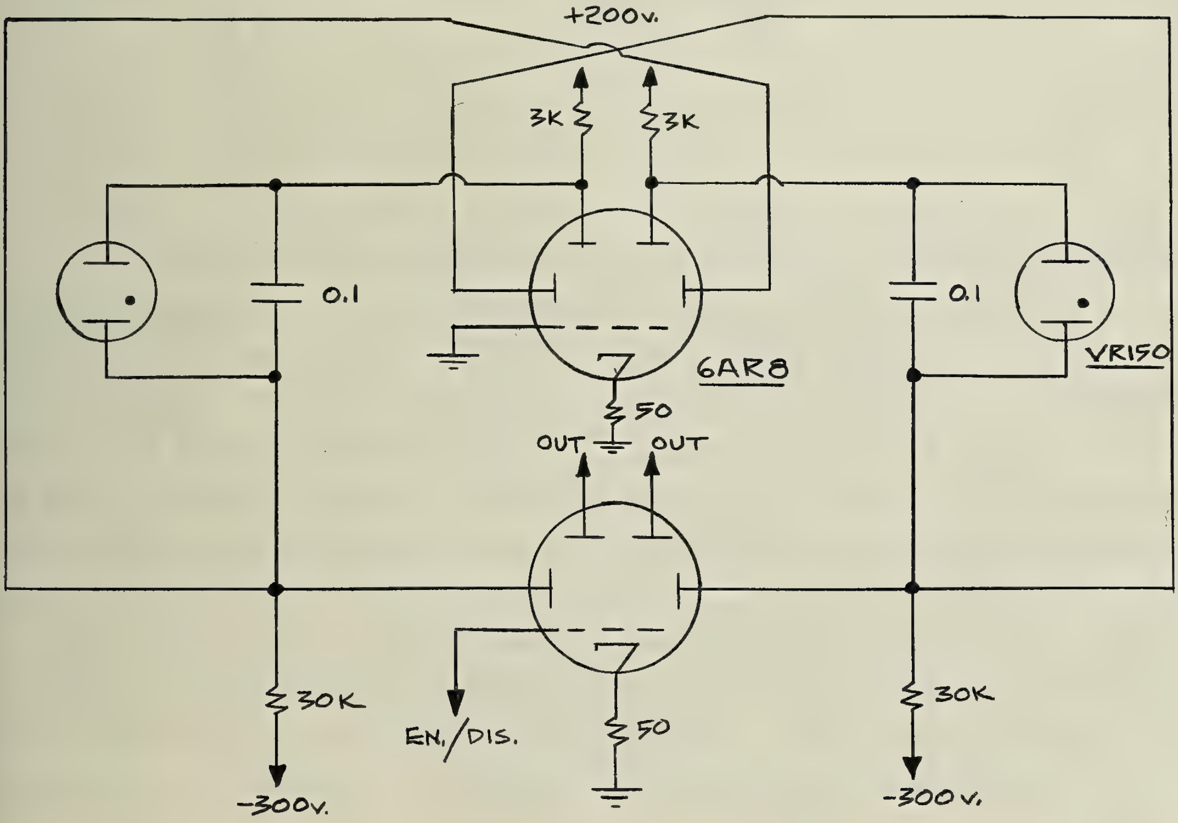


CROSSCOUPLED EMITTER FOLLOWER RACING REGISTER

The manner of operation of the crosscoupled cathode-follower flipflop is as follows: if the current in T_2 increases, the drop across its 2K cathode resistor increases and drives T_3 into cutoff. This means that the grid (and therefore the cathode) of T_4 go up to supply voltage level v_{cc}, leaving the grid of T_3 in the neighborhood of v_{cc} multiplied by the division ratio of the 3.6K, 6.2K voltage divider. Thus the upper end of the 6.2K resistor is essentially at the same voltage whether T_2 or T_3 conducts: the 6.2K resistor acts like a constant current source. But we have supposed that the current in T_2 increases: this brings its plate down and by virtue of the cathode follower the voltage drop across the 3.6K resistor decreases and therefore the current in it. Since the 6.2K resistor is a constant current source, this means that the current in T_2 must increase further still.

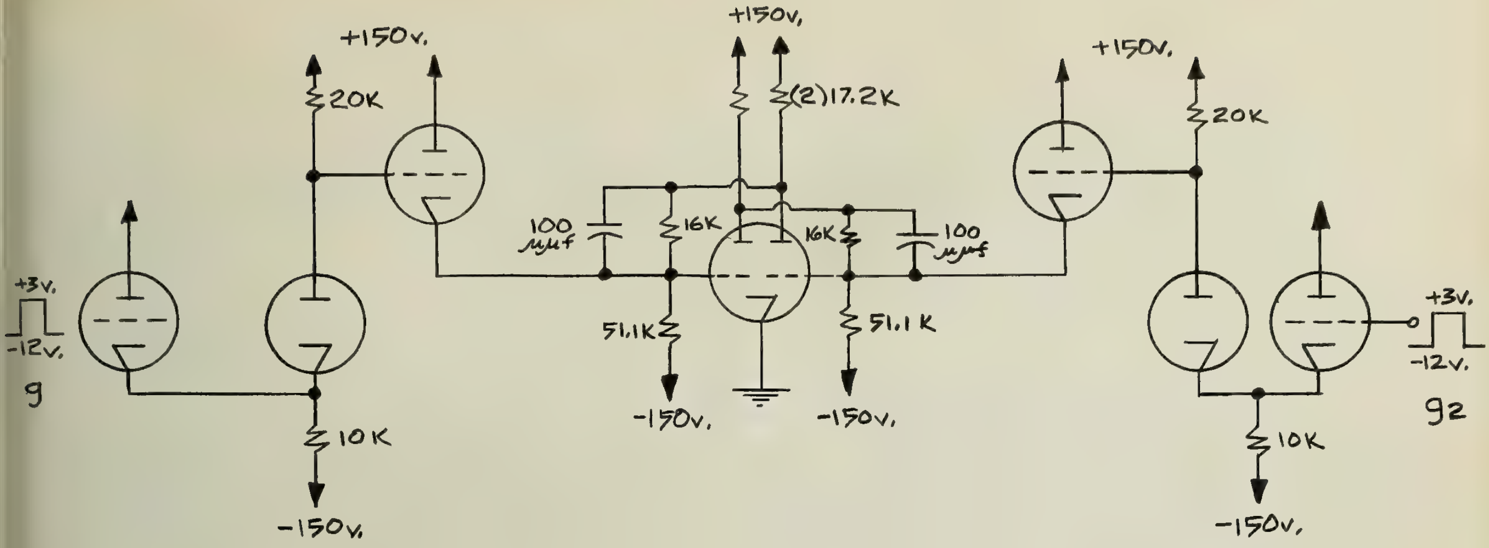


A beam-switching tube operates like a cathode ray tube, except that the beam hits a split target. In the flipflop the target plate voltages are fed back (after a suitable dc-stepdown in VR-tubes) to the deflection electrodes and it is easy to see that for a big enough load resistor the tube will be able to hold the beam in either position. The circuit is especially attractive because of its great simplicity and the natural push-pull features.

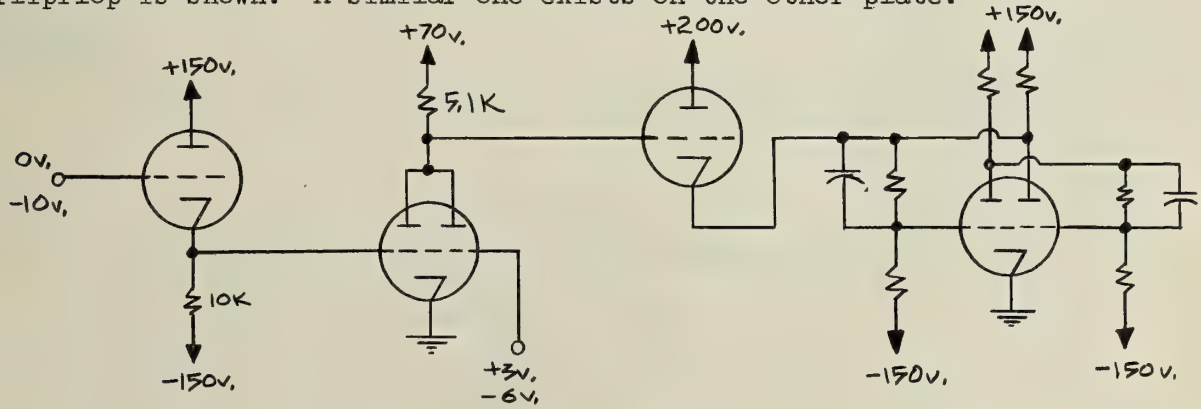


Racing registers have been built with both kinds of flipflops and the combined gating and turn-over time was 25mμs for the crosscoupled flipflops and 100 mμs for the beam-switching flipflops.

Some tests have been made on grid gating of relatively standard flipflops. The system as it was tried approximates a double gating scheme. The circuit is shown below.



This circuit was used with pulses as short as 20 millimicroseconds. The two pulses were obtained by generating one short pulse and using it at both ends of a length of coaxial cable which has a length which is electrically longer than the pulse. It was found possible to turn the flipflop over and back in about 40 to 50 millimicroseconds total elapsed time for both gates. The rise and fall times were reduced to about 10 millimicroseconds. At the conclusion of this work, it was realized that the circuit will not operate for a long sequence of gates from one flipflop to another. Since the gate circuit gain is less than one, after passing through several sequential circuits, no signal remains for gating succeeding flipflops. It is expected that the following alteration of the circuit will cure this problem. The gate into only one plate of the flipflop is shown. A similar one exists on the other plate.



It is expected that this circuit will operate slightly slower than the previous one, but the presence of gain should make it possible to use it in a longer sequence. It is also possible to use it in a racing register.

To speed up the design of the various flipflops a code was written to solve for the three resistors of the usual flipflop circuit when the power voltages, resistor and power tolerances, and desired operating voltages are specified.

VII. CONSTRUCTION.

Almost all of the effort in the shop during October was on the final drum unit. All of the basic filament wiring was completed. All of the circuits, altered where necessary, have been completed and are ready to be installed in the drum rack. The work on the drum unit which remains to be completed consists of the wiring of the preamplifier chassis in the rack, the installation of the drum and the mounting of the covers.

VIII. REPORTS AND SEMINARS.

Seminars

"Electrons and Holes in Semiconductors," by W. J. Poppelbaum, October 4, 1955.

"Flow and Continuity Equation for Carriers in Semiconductors," by W. J. Poppelbaum, October 11, 1955.

"Fundamental Transistor Equations," by W. J. Poppelbaum, October 18, 1955.

"The Cauchy Problem and Characteristic Equations." by Carl C. Farrington, October 25, 1955.

IX. PERSONNEL.

The personnel associated with the group and hence the contributors to this report are:

Bartky, Walter Scott, 1/2 time Res. Asst.
Carter, Clifford E., Electronics Engineer for Illiac
Clark, Miss Helen B., Secretary
Clements, Virgil F., Jr. Laboratory Mechanic
DeWit, Roland, 1/2 time Res. Asst.
Ehmen, Mrs. M. Gwendolyn, Computer Teletype Operator
Farrington, Carl C., 1/2 time Res. Asst.
Fishel, Jerome H., 1/2 time Res. Asst.

Goldberg, Jack L., 1/2 time Res. Asst.
Golub, Gene H., 1/2 time Res. Asst.
Holm, Walter H., 1/2 time Jr. Electronics Techn.
Huffman, Wm. L., Computer Operator II
Kerkering, Thomas E., Sr. Laboratory Mechanic
Leichner, Gene H., 3/4 time Res. Asst. (Started Oct. 1)
Lopeman, Harold E., Electronics Engineer for Illiac
Lurie, Fred M., 1/2 time Res. Asst.
Martin, Ronald D., Jr. Elec. Tech. (Started October 17)
McGinnis, Gerald A., Sr. Electronics Technician for Illiac
Meagher, R. E., Chief Engineer
Metze, Gernot A., 1/2 time Res. Asst.
Michael, George W., Administrative Assistant
Miller, Raymond E., 1/2 time Res. Asst.
Morrill, Ronald F., Draftsman
Muller, David E., Res. Asst. Prof. of Applied Math.
Nash, J. P., Res. Prof. of Applied Math.
Nelson, James C., 1/2 time Res. Asst.
Newmark, N. M., Chairman, Executive Committee
Pelg, Edmund, Jr. Electronics Technician
Poppelbaum, W. J., Res. Asst. Prof.
Robertson, James E., Res. Asst. Prof. of Elec. Eng.
Russell, Miss Ramona J., Computer Operator I
Schneberger, Edward J., 1/2 time Res. Asst.
Seshu, Mrs. Lily H., 1/2 time Res. Asst.
Stephens, Allen, Jr. Laboratory Mechanic
Taub, A. H., Res. Prof. of Applied Math.
Warner, Hohn H., Computer Operator I (Started Oct. 10)
Wenta, Joseph, Sr. Electronics Technician
Wier, Joseph M., Research Associate
Yu, Hwa-Nien, 1/2 time Res. Asst.

Student Assistants

Geis, John P.
Goodman, Robert
Hill, Robert S.
Kirwan, John F.
Ogata, Albert I.

The work of the group is under the administration of an Executive Committee with the following members: N. M. Newmark, Chairman, D.E. Muller, W. J. Poppelbaum, J. E. Robertson, J. P. Nash, A. H. Taub, and R. E. Meagher.

R. E. Meagher
R. E. Meagher

REM/hc

UNIVERSITY OF ILLINOIS
GRADUATE COLLEGE
DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

Teaching and graduate research are not, in general, reported herein.

November 1 - November 30, 1955

I. MATHEMATICAL RESEARCH AND PROGRAMMING. (This work is supported in part by the Office of Naval Research under Contract N6ori-07130.)

Boolean Algebra and Switching Circuits

A method of design was developed to obtain speed independent circuits for all scales of odd n. With the previously obtained scale of two counter, this means that speed-independent counters of any scale can be formed.

A transformation was obtained which enables one to replace the logical F-element (the single-ended flipflop) by a c-element (an element which conforms to a majority element in which the output is fed back as one of the inputs). Unfortunately, it is generally not possible to replace the c-element by an F-element and maintain speed-independent performance in the circuit.

Plans have been made for a computer program which will analyze asynchronous circuits. It will classify circuits as follows:

1. Totally sequential,
2. Speed-independent and distributive,
3. Speed-independent,
4. Not speed-independent.

In case one of the first three conditions holds, the program will also indicate whether or not the circuit stops, while if the fourth condition holds the nature of the failure will be indicated.

Several new results were obtained in the theory of speed-independent circuits. It was shown that the states of such a circuit form a semi-modular lattice. If a subset of the complete set ofnodes of the circuit is studied, the states of this subset correspond to ideals of the original lattice.

A report is to be prepared (Internal Report No. 66) which will define the terms mentioned here and which will discuss the results in detail.

Floating Address and Compiling Routines

That part of the floating address program which forms the list of addresses has been checked out, and some useful modifications in the section which replaces the Williams memory address in those words having pseudoaddresses have been made. The location of the Decimal Order Input routine will now be changed to make way for housekeeping orders of the floating address program. Work is

also continuing on the investigation of an appropriate compiling routine to work with the floating address routine.

Post Mortem Routines

A workable form for the combined post mortem routine for the magnetic drum has been determined and is now being programmed. This routine will retain the features of Library Routine C-10 and will include the Address Search Routine, C-6. The Post Mortem Version of the Decimal Order Input, which is the basic post mortem routine, will be included at a later date when the final form of the new Decimal Order Input routine has been decided upon and completed.

II. ANALYTICAL PROGRAM. (This work is supported in part by National Science Foundation through Grant G-1221.)

The study of the motion of a fluid or gas in its own gravitational field is a problem in general relativity, which has applications in astrophysics. The problem has been formulated mathematically for isentropic motions of a compressible fluid in a space-time admitting plane symmetry by using a co-moving coordinate system.

The interpretation of these equations is made through the use of co-moving coordinates in special relativity. The relation between these coordinates and the Lagrangian coordinates of classical hydrodynamics has been studied in detail. The problem of determining static solutions of space-times admitting plane symmetry has been reduced to the solution of an ordinary differential equation. The nature of this differential equation depends on the caloric equation of state of the fluid whose presence creats a gravitational field. Similar methods may be used on space-times admitting spherical symmetry. It is planned to derive the corresponding ordinary differential equation and to integrate it numerically for various simple caloric equations of state.

III. PROGRAM LIBRARY.

The following new program was added to the active library. It was prepared by Mr. Leroy Augenstine of the Control Systems Laboratory.

K-10 (191) *Calculate Autocorrelation of a Time Series. 85 words.* This is a closed routine with four parameters which are used to define the number and location of the variables, the lag, and the location of the calculated autocorrelations.

The following new programs have been added to the auxiliary library. K-9 was prepared by Professor W. C. Jacob of the Agronomy Department, K-11 by messrs. J. O Neuhaus and R. J. Twery of the Psychology Department, and F-4 by Messrs. R. A. Rubenstein and S. Machlup and Mrs. Marjorie Huse of the Physics Department.

K-9 (190) *Product Moment Correlations, Means, Standard Deviations, Variances and Covariances in Logarithmic Scale. Complete Program.* This program is the same as K-2 except for a modification which takes the logarithm of each number as it is read in.

K-11 (192) *Quartimax Orthogonal Rotation of Factors. Complete Program.* This program is a method of rotation which finds the orthogonal transformation which maximizes the variance of the squared factor loadings. The method is equivalent to maximizing the fourth powers of the loadings. If p is the number of variables and m is the number of factors, the capacity is limited by $m \cdot p \leq 745$.

F-4 (198) *Numerical Solution of the Schroedinger Equation for Central Fields. Complete Program.* This "program" is actually a set of versatile programs capable of handling Schroedinger problems for any spherically symmetric potential, positive and negative energy states, up to five wave functions simultaneously. In their present state the programs can

(1) find eigenvalues (permitted negative energies);

(2) print out values of thewave functions at regularly spaced intervals, and find the nodes and extrema;

(3) evaluate matrix elements (transition probabilities, normalization integrals, dipole moments, etc.;

(4) solve self-consistent field problems.

The Noumerov method is used for integration and a five-point extrapolation-iteration scheme is provided for finding the initial value of the second derivative of the wave function.

Y-3 (201)

Input Routines to Drum Memory. 148 words. This is a closed routine which will take any library routine and store it on the drum, preserving all of the terminating symbols of the Decimal Order Input (Library Routine X-1).

M-17 (197)

Post Multiplication of a Matrix A or Its Transpose A^T by a Vector k. 45 words. A closed routine with one program parameter, this program is designed for use with Library Routine N-9, the input routine which stores only the non-zero elements of a matrix.

IV. MACHINE USE.

During November specifications were presented for 16 new problems. This list does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 690. Numbers followed by T are for theses.

690 Physics. Pinning of Dislocation Lines by Impurity Atoms. The problem is concerned with a 3-dimensional lattice which is regular in only one direction. Sums are carried out over some 5,000 ion rows.

691 T Electrical Engineering. Evaluation of a Transfer Function. The problem, which arises in the study of a servomechanism system, requires the evaluation of some complex partial fraction expansions.

692 Computer. Flipflop Resistor Chain. The program uses an iterative scheme to solve for the three resistances in a flipflop chain when the supply voltages, down plate voltage, up and down grid voltages, plate current, grid current, power supply tolerance, and resistor tolerance are given.

693 Psychology. Analysis of Test Structure. The quartimax method is used to interpret the results of several tests.

694 Agricultural Economics. Farm Planning by Linear Programming. The problem is to select optimum farm organizations for typical farm situations, the variables being soils, supplies, and other resources.

695 T Electrical Engineering. Performance of a Non-linear Servo System. The Runge-Kutta method will be used in the integration of the differential equations describing a potentially linear nth order servo system as the servo motor torque is made several different functions of the state of the system in phase space.

696 Structural Research Laboratory. Multi-Degree-of-Freedom System. The program uses Newmark's method for the integration of a system of second order differential equations.

697 Mathematics. Efficiency of Systematic Sampling. An investigation is being made of the efficiency of systematic sampling in which n elements are selected from a population of N = kn elements by ordering the population, choosing randomly one of the first k elements, and then taking that element and every kth element thereafter. Several populations will be studied.

698 T Physics. Band Structure of Aluminum. The program combines the quantum defect method with a determinantal method.

699 Computer. Floating Address Routine. This is a test of the input routine to be used with the floating address program.

700 Mathematics. Tournament Method of Sorting. This program solves the problem of picking from a list of n numbers the k largest.

701 Mathematics. Automatic Data Shuffler. In sorting n numbers into a list of decreasing magnitude, the data are partitioned into a number of groups of size as near n as possible and then these are sorted.

702 Institute of Communications Research. Comparison of R and Q Techniques of Factor Analysis. The computation is carried out through use of a number of library routines.

703 Psychology. Investigation of Second Order Factors. A set of intercorrelations already obtained from correlating oblique reference vectors will be factored using the Principal Axes Method of Factor Analysis, Library Routine M-7.

704 Chemistry. Statistical Properties of Real Polymers. The problem is concerned with the study of random walks in lattice structures different from a ninety-degree lattice.

705 Structural Research. Solution of Rectangular Plate Deflection. Library Routine L-2 is modified to solve the simultaneous equations resulting from writing the network of special finite difference equations for a plate simply supported on three sides and with a variable stiffness beam on the fourth side.

Table I shows distribution of machine time for the month of November.

TABLE I

Regular Maintenance and Illiac Engineering	47:27
Unscheduled Maintenance or Repair	16:53
R.A.R.	5:52
Leapfrog	43:25
Wasted	:30
Use by Departments	
Computer Group	6:51
Physics	115:48
Control Systems Laboratory	67:49
Structural Research	29:59
Structural Research (AF 24994)	8:10
Psychology (AF 25726A)	5:28
Industrial Education (AF 1350)	2:39
Psychology	9:06
Electrical Engineering (AF 310)	:30
Electrical Engineering	1:07
Chemistry	18:50
Cosmotron	98:36
Agriculture	11:27
Economics	5:44
Inst. of Communications Research (PH 3M9067)	:14
Inst. of Communications Research	1:53
University of Rochester	:38
Classes	:05
Demonstrations	8:36
Miscellaneous	4:18
Total	511:55

V. ERROR FREQUENCY AND ANALYSIS.

The machine is normally used for "engineering" and maintenance between 8:00 A.M. and 12:00 N, and for a check of its performance between 6:00 and 6:30 P.M. of each weekday. Since the periods between 8:00 A.M. and noon, together with certain irregular periods like Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more instructive from an error analysis standpoint to look at the periods between noon and 8:00 A.M. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind, a summary table has been prepared using the period between noon and 8:00 A.M. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 6:00-6:30 P.M. period (when the machine is checked) if no errors are found, the time is given to the "running column." Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that any interruption of machine time that was not planned for is considered a failure in this table. In rare cases where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This overall system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running at any instant of time and the probability of a failure during any given interval of running time.

VI. COMMENTS ON THE ILLIAC AND RELATED FACILITIES.

Table III presents a summary of errors or interruptions for November.

DATE	RUNNING OK RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
11/1/55	17:14	2:46	3	(1) Reader "J" - pin came out of brake. (2) Punch failure (4) (3) 2-^{38} RII row 3 (?)	:00	1:22	1
11/2/55	19:18	:42	1	(1) Punch No. 4 failed to punch an 8.	:00	1:12	1
11/3/55	19:59	:01	1	(1) Input-output failure	:00	1:01	1
11/4/55	19:59	:01	1	(1) Reader "I" tore tape.	:00	2:31	0
11/7/55	20:00	:00	0		:00	:42	0
11/8/55	19:37	:00	0		:23	:55	0
11/9/55	19:35	:25	1	(1) Reader "F" failure.	:00	:26	0
11/10/55	19:59	:01	1	(1) Reader "I" failure.	:00	:53	0
11/11/55	19:24	:33	3	(1) Reader "H" failure. (2) Reader"H" failure, clutch does not engage. (3) Reader "H" failure.	:03	1:05	0
11/14/55	19:45	:15	3	(1) Reader "J" error. (2) Reader "J" error. (3) Reader "J" error.	:00	1:56	0
11/15/55	14:59	5:01	4	(1) Punch No. 3 missing 8 and 4 holes. (2) Reader "H" error. (3) Reader "E" error, tore tape. (4) Reader control chassis, bad tubes.	:00	:34	0
11/16/55	19:07	:53	7	(1) Reader "J" tore data tape. (2) (3) (4) Fuzzy holes from printer and static electricity caused reader error. (5) Reader "E" error. (6) Reader "J" tore tape. (7) Reader "C" failure.	:00	:36	0
11/17/55	17:03	2:56	4	(1) (2) (3) (4) Fuzzy sprocket holes and static electricity caused reader error.	:01	:30	0

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
11/18/55	19:53	:00	0		:07	1:05	0
11/21/55	19:59	:01	1	(1) Reader "G"tore tape.	:00	1:04	0
11/22/55	20:00	:00	0		:00	:48	0
11/23/55	19:18	:37	1	(1) Reader "H" failing to read 5th hole	:05	1:36	0
11/25/55	20:00	:00	0		:00	1:25	0
11/28/55	19:07	:53	3	(1) Reader "I" light out. (2) 2^{-2} failure 0 → 1 (3) Comparison failure 2^0	:00	2:08	2
11/29/55	19:32	:28	2	(1) Reader "H" - filament range shifted (2) Hesitating on execution of 75 orders	:00	1:30	0
11/30/55	19:22	:38	3	(1) No B. C. enable, Connections open on V26 input-output shift control (2) Answers to Fosdick's problem reported incorrect. (3) Reader error (?)	:00	1:15	0
Totals	403:10	16:11	39		:39	24:34	5

TABLE III

Summary of Errors

Arithmetic unit	1
Control	1
Reading combined with punching	8
Reading only	21
Punching only	3
Memory	2
Reader control	1
Input-output control	1
Unknown	1
Total	39

During the month engineering effort on the drum storage unit consisted mainly of checking preamplifier chassis and other new chassis for the final drum unit. At the end of the month the wiring of the unit was complete except for the cables between the preamplifiers and the drum.

VII. RESEARCH ON COMPUTER COMPONENTS. (This work is supported in part by the Office of Naval Research under Contract N6ori-07124.)

Fast Vacuum Tube Circuits

As was mentioned in the progress report for October, a fast vacuum tube gating system with a gate with some gain was tried. The form of the circuit is shown below.

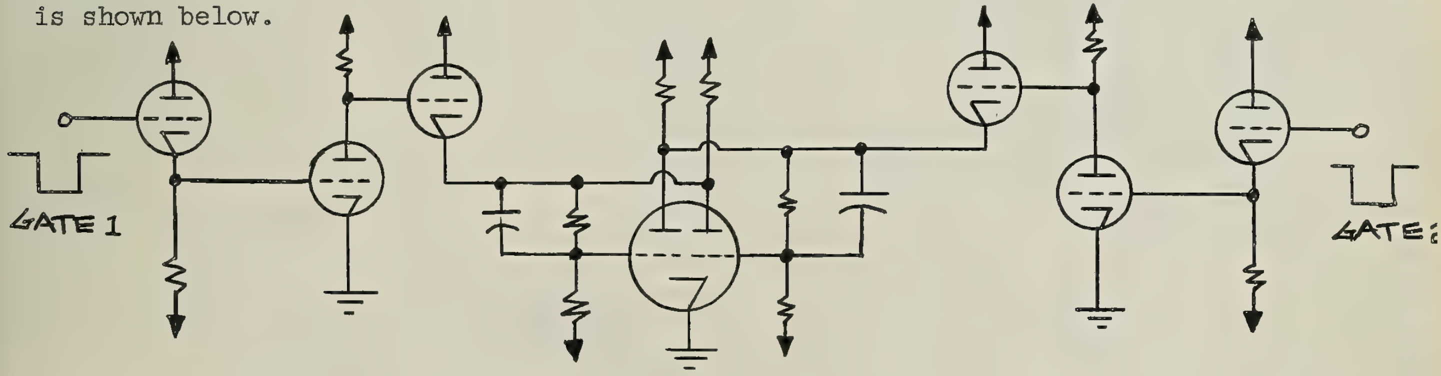


Figure 1

The two negative pulses were supplied by making one pulse and using it twice, once at each end of a coaxial cable. It was found that pulses of duration 20 millimicroseconds were sufficiently long to turn the flipflop over. The best rise times obtained at the flipflop were about 10 millimicroseconds. The actual time elapsed from the start of the gate pulse until the flipflop is turned over to its final state is about 30 to 35 millimicroseconds. Thus the gate pulse has been completed before the end of the process. Obviously the stray capacities that are charged during the gating pulse are the driving sources for the latter part of the process when the gate pulse has been completed and the circuit is still moving. All observations were made by going into the observing scope on the deflection plates.

A report on the recent vacuum tube circuit work is now being prepared.

Fast Cross-coupled Transistor Circuits

Surface-barrier transistors with 60mc α-cutoff frequency received in November permitted us to obtain operation times of the order of 30mμs with the racing register described in the last issue. In order to obtain a bigger swing and a greater speed, the flipflop was redesigned. The flipflop-gate-complex now uses the values given below (Figure 2). The minimum operation time obtained was about 20 mμs. A more detailed consideration of the mechanism of the flipflop shows that with presently available transistors the minimum time obtainable is in the neighborhood of 10 mμs. It is not thought practical to continue research in this direction for the time being.

A fairly simple way of treating the tolerance problems of cross-coupled flipflops was devised. For this we consider Figure 3 in which one-half of the flipflop is split into its two constituents: the emitter-follower (input voltage g', output voltage w') and the amplifier (input voltage u', output voltage f'); the voltage $-u_o$ is treated as a parameter. To simplify, it is assumed below that the transistors involved have $\alpha = 1$. The more general discussion uses the same principles. Introducing

$$f_o = -v_o \frac{R_1 + R_2}{R_1 + R_2 + R_3} + V \frac{R_3}{R_1 + R_2 + R_3}$$

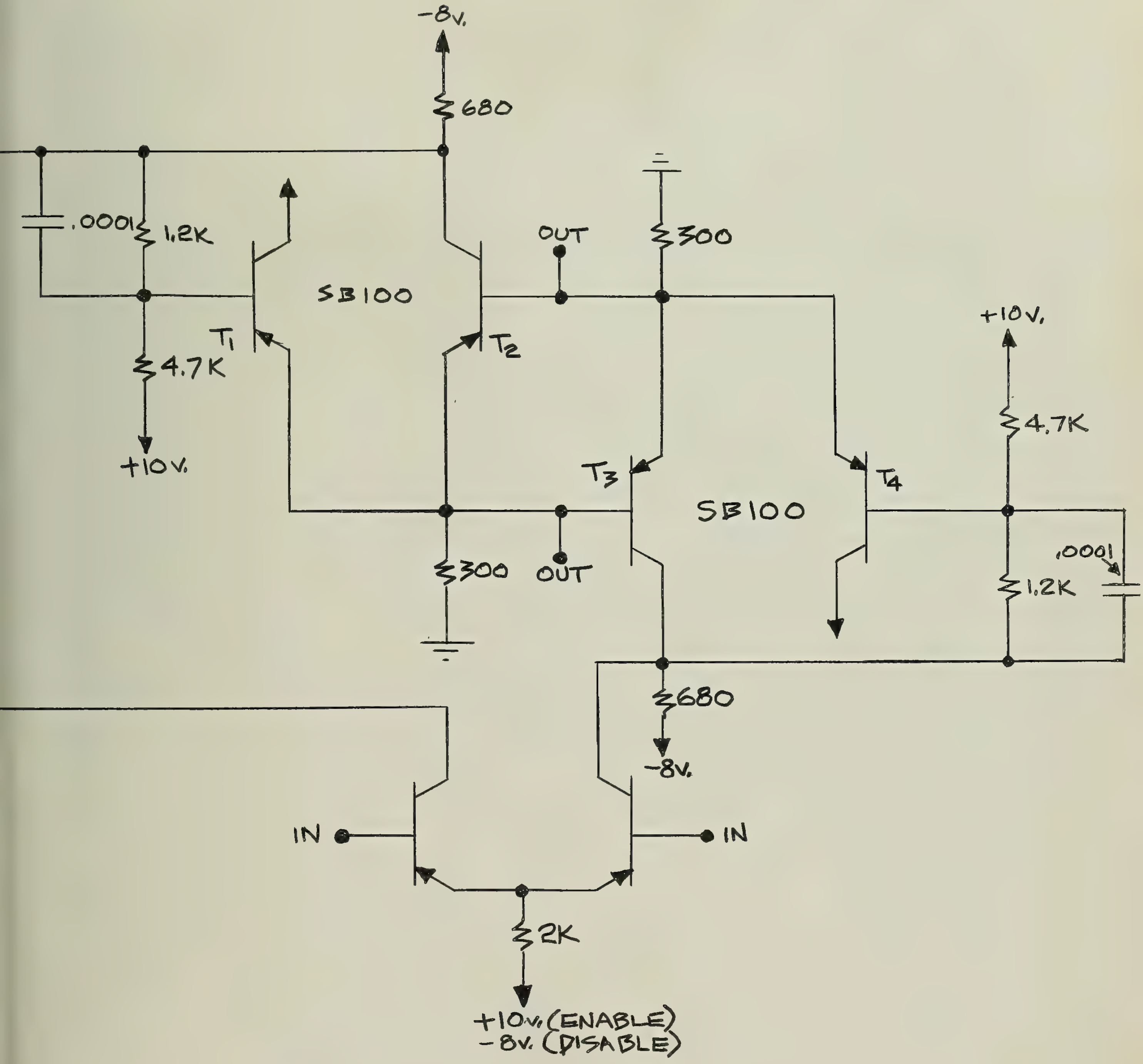

-8V.
680
.0001
1.2K
SB100
OUT
300
T1
T2
4.7K
+10V.
+10V.
T3
T4
SB100
4.7K
300
OUT
.0001
1.2K
680
-8V.
IN
IN
2K
+10V. (ENABLE)
-8V. (DISABLE)

FIGURE 2

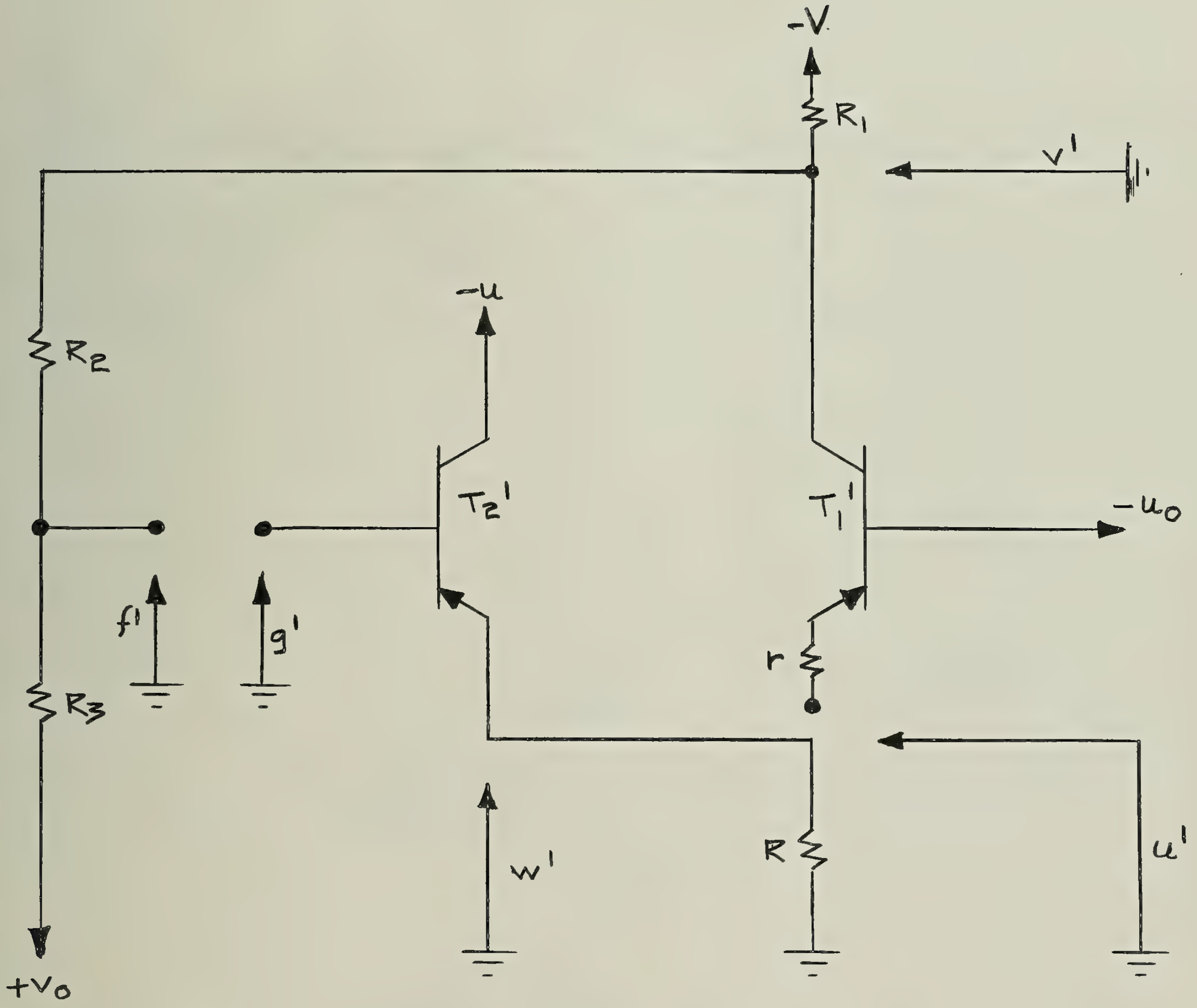


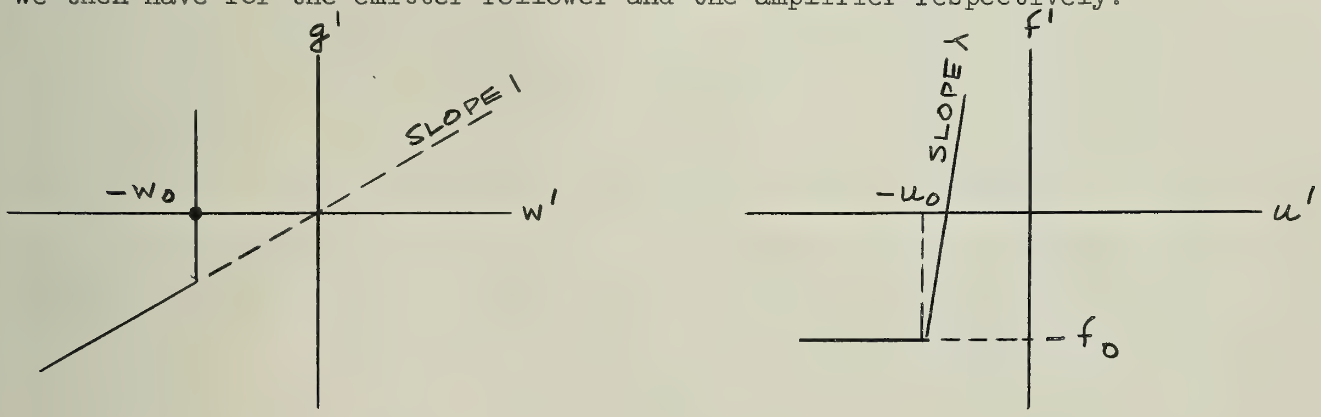
FIGURE 3

$$\lambda = \frac{R_1 R_3}{r(R_1 + R_2 + R_3)}$$

$$\gamma = \frac{R}{r + R}$$

$$w_o = \gamma u_o$$

We then have for the emitter-follower and the amplifier respectively:



Emitter-follower

Amplifier

Figure 4

Giving the two stable states 1 and 3 by a combined graph:

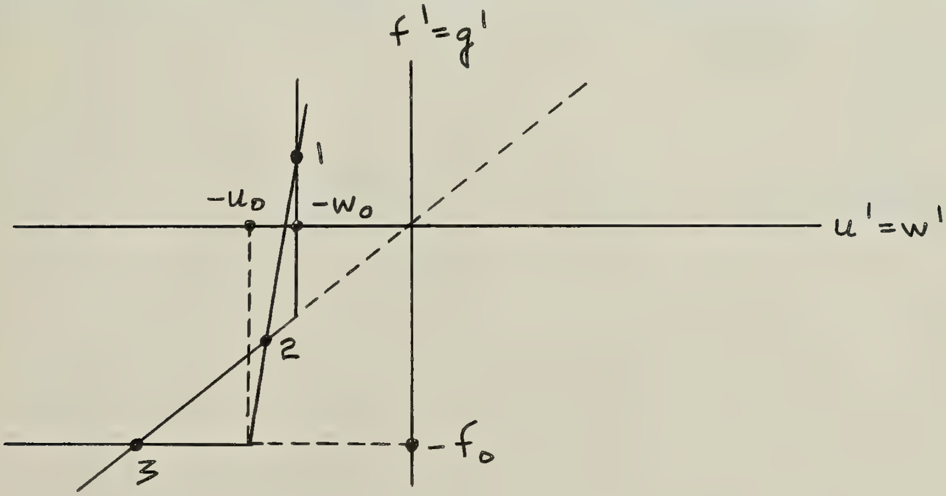


Figure 5

Repeating this construction for the different values of u_o (which modifies $w_o = \gamma u_o$!) we obtain the "state-graph" for one-half of the flipflop:

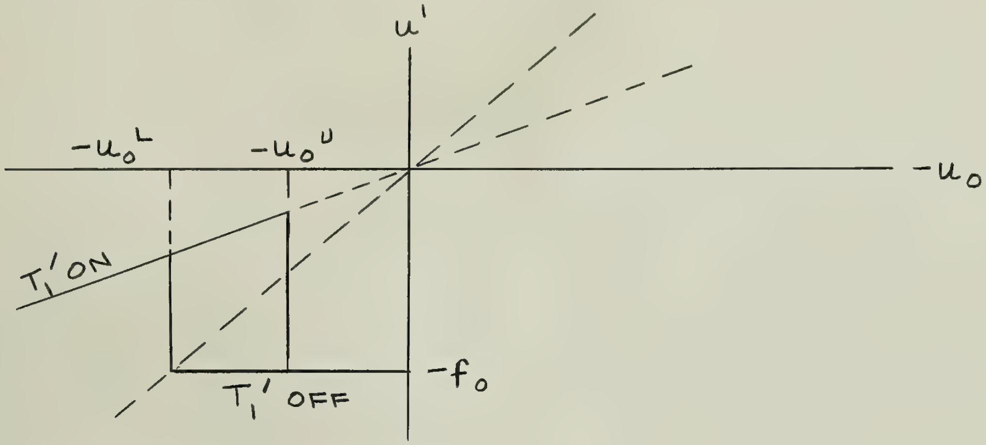


Figure 6

where

$$u_o^L = f_o$$

$$u_o = \frac{f_o}{\lambda - \lambda\gamma + \gamma}$$

Combining this graph with a similar one for the second half (with T_1'' as emitter-follower), we obtain the stable states of the crosscoupled flipflop. In the figure f_o^* and u_o^{U*} refer to the right-hand half of the flipflop: the dashed part of the figure is similar to the loop in the u', - u_o plane, but the axes are interchanged. The possible states of the system are given by the intersection of "T_1' on" with "T_1'' off" and "T_1' off" with "T_1'' on."

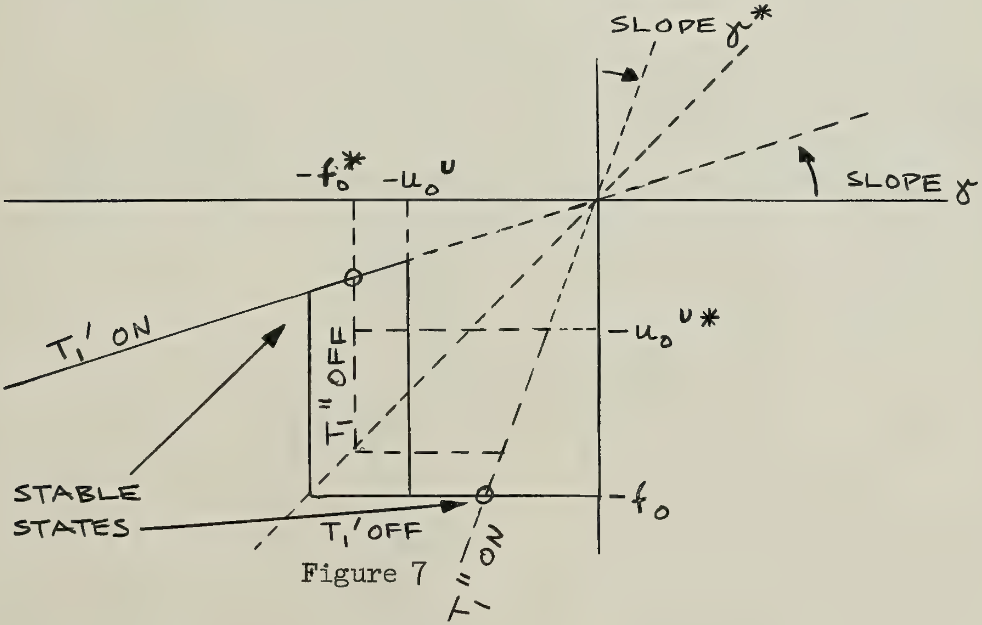


Figure 7

Discussing tolerances now simply means replacing the two lines "T_1' off" and "T_1'' off" by bands of appropriate width and the two lines through the origin by fan-shaped sectors of calculable angular opening.

Fast Eccles-Jordan Transistor Circuits

A racing register was constructed using surface-barrier transistors in a cathode coupled nonsaturating Eccles-Jordan circuit. A two flipflop circuit recirculated at about 0.12 to 0.13 microseconds. Thus it might be stated that the operation time is about 30 millimicroseconds per flipflop turnover. Actually, since the succeeding flipflop is instructed to turn over before the previous one has completed its swing, the actual turnover time is probably nearer to 60 millimicroseconds than to 30 millimicroseconds.

Fast Logical Transistor Circuits

In order to carry out logic at these high speeds a complete set of logical elements is required. With a single type of transistor, either npn or pnp, it is possible to obtain either an and circuit or an or circuit with a very fast emitter-follower type circuit which is completely analogous to the Illiac and circuit. A typical circuit for npn transistors is shown below.

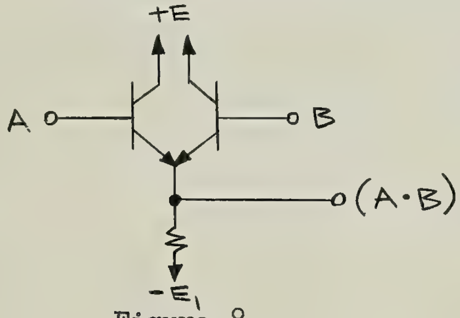


Figure 8

If both npn and pnp transistors become available, a corresponding circuit may be made to yield the other one of the and-or set. The pnp equivalent of the circuit above yields an or circuit in the same system of logic.

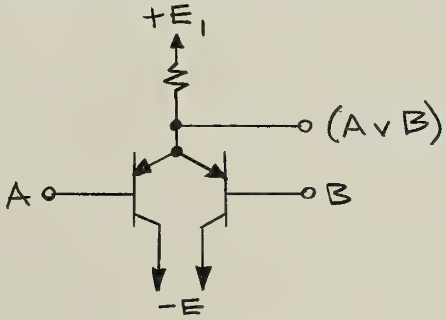


Figure 9

Since a marginal speed advantage is obtained by using pnp transistors, most manufacturers are making pnp devices. This is particularly true in the high speed transistor field. Thus a premium is placed on complete logical set of circuits which is constructed of one type of transistor only.

Another difficulty associated with transistor circuits is the rather complex type of not circuits which seem to evolve for sufficiently tolerance-safe circuits. These circuits actually are about as complex as the flipflop circuits themselves and actually are quite slow compared to the and and or circuits listed above when constructed of the same transistors. This is true even when both pnp and npn transistors are available. Therefore two sets of circuits were devised to circumvent this problem. One of these presupposes both types of transistors. The means of avoiding the necessity of having an overt not circuit is to carry about both a signal and its complement at all points in the logical circuitry. With the npn-pnp arrangement the topologically similar and and or circuits listed above were proposed. Since it will be necessary in this system to generate both the logical function and its complement at each point in the circuit, a somewhat more complex logical structure is necessary. Assume that it is desired to obtain both $(A \cdot B)$ and $(A \cdot B)'$, given A and A' and B and B'. Then $(A \cdot B)$ results directly from the use of the and circuit. Using the or circuit and A' and B', $(A' \vee B') = (A \cdot B)'$ is generated which is the required complement. In a completely symmetrical manner $(A \vee B)$ may be obtained directly and the and circuit may be used to obtain $(A' \cdot B') = (A \vee B)'$. Thus the not circuit is avoided at the expense of increased and-or circuitry and the requirement that all flipflops be of the symmetrical type.

Another system of achieving this end with transistors of only one type is shown below. Here the and and or circuits are identical in form and the inputs are presumed to be of a push-pull form, that is the logical value is arranged to be a function of only the difference in voltage between the terminals giving A and A' rather than the magnitude of the voltage at either terminal as in the above set. The circuit shown below is marked as it would be for an and circuit. The or circuit is obtained by reversing the A and A' connections and the B and B' connections. The circuit shown uses only pnp transistors although an exactly analogous circuit is available using the npn type.

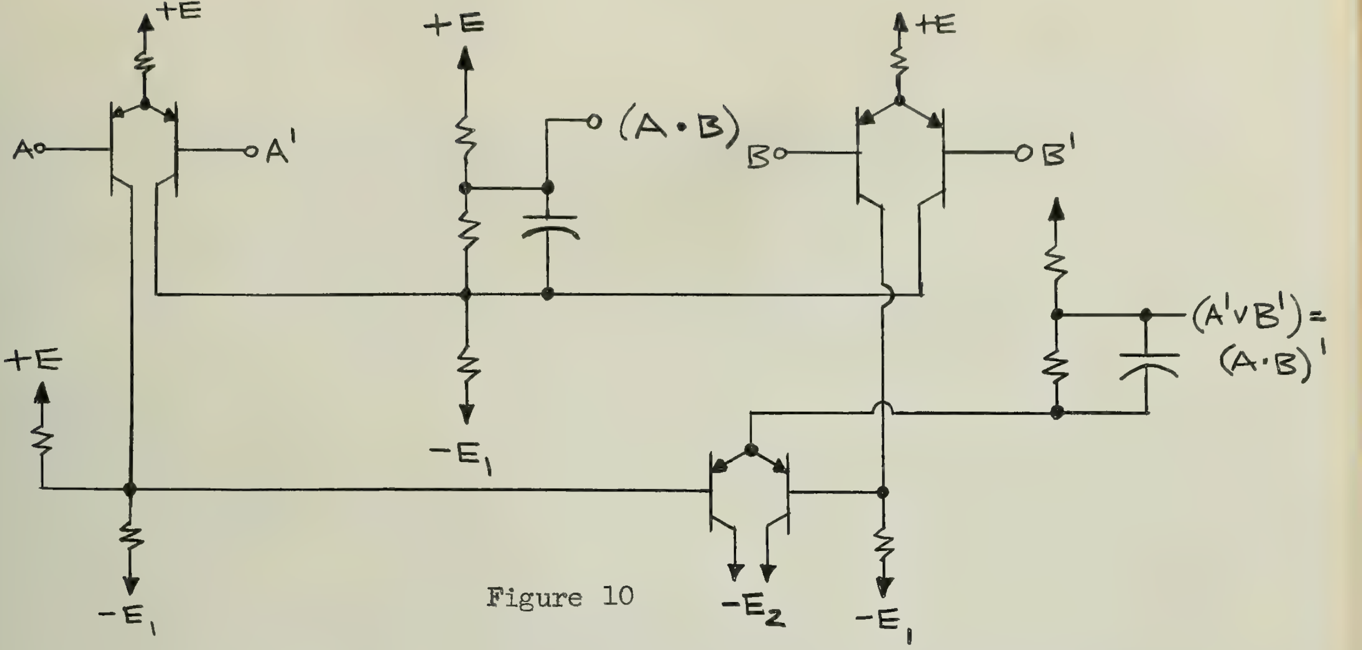


Figure 10

It is evident that this circuit will be of a slower type than the emitter-follower class, but it does use only one type of transistor. It also has gain so degeneration is no problem in its use.

In order to achieve operating circuitry without the ultimate in transistors, certain high speed circuits have been designed whose speeds of response are a function almost solely of the transistors used in the circuits. Thus these circuits may be tested with slower transistors for certain tolerance features until faster ones are available and then these faster transistors may be used to obtain the desired circuit speeds.

VIII. CONSTRUCTION.

The shop has completed the final drum auxiliary memory except for fitting the covers to the frame unit and making up the cables between the individual drum reading and writing heads and the preamplifier chassis.

IX. REPORTS AND SEMINARS.

Seminars

"Properties of Characteristic Curves and the Numerical Integration of the Characteristic Equations" by Carl C. Farrington, November 1, 1955.

"Numerical Computation of the Characteristic Values of a Real Symmetric Matrix" by Gene H. Golub, November 8, 1955.

Seminars (Cont.)

"Automatic Network Analysis with a Digital Computational System" by E. J. Schneberger, November 15, 1955.

"A Boolean Algebra Involving Delays" by G. A. Metze, November 22, 1955

"Review of Logic for Digital Computer Adder Carry Circuits" by Raymond E. Miller, November 29, 1955.

X. PERSONNEL.

The personnel associated with the group and hence the contributors to this report are:

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R. E. Meagher.
R. E. Meagher

REM/hc

UNIVERSITY OF ILLINOIS
GRADUATE COLLEGE
DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

Teaching and graduate research are
not, in general, reported herein.

December 1 - December 31, 1955

I. MATHEMATICAL RESEARCH AND PROGRAMMING. (This work is supported in part by the Office of Naval Research under Contract N6ori-07130.)

Boolean Algebra and Switching Circuits

Three theorems on composition and two on decomposition of speed independent circuits have been found. The theorems on composition show that any delay elements present in a speed independent circuit may be removed without affecting its behavior or speed independence and that two elements which statically behave as a single element may be combined in a speed independent circuit without affecting the behavior of the circuit or its speed independence. The theorems on decomposition show that if a single element is decomposed into a set of elements in a speed independent circuit, any violation of speed independence in the new circuit may be discovered by investigating only possible violations which are concerned with the new elements.

A synthesis theory has been developed for speed independent circuits and seems to yield a practical design method for such circuits (including registers, gates, adders and control circuits). It consists of starting with a synchronous circuit design and replacing certain sets of elements with new speed independent sets. The technique, which appears to be particularly applicable to transistor circuits, also allows the use of conventional flipflops in the design with the exception of three elements in the entire circuit.

Continued Fraction Expansions

A continued fraction expansion has been used to evaluate e^x for $-1 < x < 0$. The program for carrying out the computation has the same accuracy (2^{-39}) and the same speed (13 milliseconds) as the power series method in the present library routine but requires only 19 words of program instead of the present 33. Additional speed may be obtained by sacrificing accuracy. For example, if the range is restricted to $-1/2 < x < 0$ and one word of the routine is changed, the accuracy will be about 4 decimal places but the time required will be reduced by about 7 milliseconds.

Sturm-Liouville Systems

Four routines for the Sturm-Liouville problem were written, one being a routine for diagonalizing a quadratic form by completing the square.

This routine will have useful applications elsewhere also. A considerable improvement in the algorithm for computing the elements of the matrices L and M in the equation $Ly = \mu My$ from which the eigenvalues and eigenfunctions are computed has been made. This has reduced the storage requirement so that, without repeating any computations, only $N(N + 2m + 3) + m + 1$ memory locations will be needed, where N is the order of the matrices L and M and m is the degree of the polynomial arcs used to approximate the function $y(x)$.

Floating Address and Compiling Routines

The last of the main blocks of the floating address routine were completed, and a rough outline of the sequencing of the compiler operations was decided upon. Two problems still remaining are the treatment of interludes and the use of absolute addresses.

Statistical Applications

A good portion of a multiple regression routine has been worked out and much of it has been checked.

II. ANALYTICAL PROGRAM. (This work is supported in part by National Science Foundation Grant G-1221.

A paper, entitled "Isentropic Hydrodynamics in Plane Symmetric Space-Times" was prepared for publication. In this paper use is made of a form of the stress energy tensor of a perfect fluid, previously derived for special relativity, to show that for irrotational isentropic motions a co-moving coordinate system exists in which both sides of the Einstein graviational field equations may be expressed in terms of the dependent variables of the self-gravitational problem for a perfect fluid. It is shown that for a space-time with plane symmetry the field equations and the assumption of isentropy imply the conservation of mass. General methods for dealing with these field equations are given for the static and s atially independent cases. Approximate solutions are obtained for other specific cases. The general exact solution is obtained for the incompressible case. Properties of the incompressible case are discussed.

III. PROGRAM LIBRARY.

The following two new programs were added to the active library. Library Routine V-6 was prepared by Professor J. N. Snyder of the Physics Department.

V-6 (202)	Associated Legendre Functions. 80 words. This is a closed routine for calculating a table of functions. The routine operates in three parts: 1) calculation of the unnormalized Legendre Polynomials, 2) calculation of starting values for a recursion relation, and 3) calculation of the associated functions by means of the recursion relation.
FA-2 (203)	Floating Decimal Solution of a System of Ordinary Differential Equations. 45 words + function routine. This routine is a closed auxiliary for Library Routine A-1, which itself requires 168 words. Except for its use of floating decimal representation, it is similar in operation to Library Routine F-1 and is intended to advance, with the Runge-Kutta method, the solution of a set of simultaneous first order differential equations.

IV. MACHINE USE.

During December specifications were presented for 17 new problems. This list does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 706. Numbers followed by T are for theses.

706 Computer. Floating Point Runge-Kutta. This was a test of a new library routine which had recently been prepared.

707 Electrical Engineering. Magnetic Current Loop. This problem is concerned with a numerical integration to solve the field equations arising from a ribbon of magnetic current encircling a dielectric rod.

708 Psychology. Analysis of Elementary School Child Personalities. Through the calculation of a matrix of ∅ coefficients, a centroid factor analysis, and rotation of factors, an analysis will be carried out on a personality inventory of 251 items administered to 168 elementary school children.

709 T Physics. Photo-nuclear Cross Section Analysis. This problem, part of which is programmed with floating point representation, will be used to predict how the photo-neutron cross section varies with energy very near the threshold energy.

710 MURA. RF-Acceleration. This program takes the particle in the synchrotron through the acceleration cycle which will be achieved by up to 8 radio-frequency cavities variously spaced around the machine. The voltage amplitude and the frequency of the RF voltage impressed on each cavity can be a given function of time during the acceleration cycle.

711 Computer. Multiple Regression Routine. This will be a library program designed to compute regression weights.

712 Computer. The Calculation of Bernoulli Numbers. The program is designed to calculate the first 1000 Bernoulli numbers as fractions.

713 Physics. Proton Flux. This program consists of solving a number of simultaneous linear algebraic equations.

714 T Corn Production in South Africa. A multiple correlation routine will be used to estimate the effect of various factors on the yield and profits of corn in the Union of South Africa.

715 Computer. Demonstration of Prime Pairs. This is a slight modification of the present prime number routine to make it print only prime pairs. It uses the principle that $6n \pm 1$ is a prime pair if there are no divisors of n of the form $6m \pm 1$ which give remainders of $\pm m$.

716 Institute of Communications Research. Prediction of Stimulus Complex. A theoretical model for the stimulus complex is used to obtain predicted scores through the substitution of some 1800 pairs of values into an equation. These predicted values will then be compared to the obtained scores gathered from testing.

717 Psychology. Interrelationships and Behavior in a Level of Aspiration Type Situation. The problem is to delineate and offer a theoretical explanation of relationships between the level of aspiration data, data on the perceptions of self and others, and data from an item analysis of the F-scale. The computation involves a solution of several large correlation matrices and is expected to be handled through the use of library routines.

718 Mathematics. Solution of a System of Differential Equations by Milne's Method with Variable Increment. This program is designed to use essentially the method of Library Routine F-2 but with provision to vary the increment of the independent variable depending on the number of iterations required for convergence. A certain amount of automatic scaling will also be done by the routine.

719 Computer. Transistor Flipflop Design. An iterative method is used to solve a set of 5 non-linear algebraic equations. The solutions of the equations provide circuit values for a transistor flipflop.

720 Electrical Engineering. Slotted Wave Guide. The problem required finding complex roots of a transendental equation in order to compute the complex propagation constant of an electro-magnetic wave traveling down a periodically slotted wave guide.

721 Physics. Proton Flux Distribution. A least-squares or maximum-minimum process will be used to compute values at a mesh of points for direct use in evaluating by analog means the necessary line integrals occurring in a low energy meson distribution.

722 Aeronautical Engineering. Eigenvalues of a Symmetric Matrix. Library Routine N-3 will be used to find the eigenvalues for 4 symmetric matrices of order 10.

Table I shows distribution of machine time for the month of December.

TABLE I

Regular Maintenance and Illiac Engineering	43:15
Unscheduled Maintenance or Repair	13:17
R.A.R.	5:07
Leapfrog	79:30
Wasted	:40
Use by Departments	
Computer Group	29:44
Physics	57:31
Control Systems Laboratory	74 34
Structural Research	4:38
Structural Research (AF 24994)	4:02
Psychology	:50
Psychology (Navy Task 35)	:10
Electrical Engineering	2:27
Electrical Engineering (AF 3320)	:09
Chemistry	22:30
Agriculture	11:02
Cosmotron (MURA)	113:33
Economics	3:03
Theoretical and Applied Mechanics (ONR 07153)	2:11
Institute of Communications Research	:37
University of Rochester (Physics Dept.)	21:26
Classes	12:10
Demonstrations	:49
Miscellaneous	8:35
Total	511:50

V. ERROR FREQUENCY AND ANALYSIS.

The machine is nromally used for "engineering" and maintenance between 8:00 A.M. and 12:00 N, and for a check of its performance between 6:00 and 6:30 P.M. of each weekday. Since the periods between 8:00 A.M. and noon, together with certain irregular periods like Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more instructive from an error standpoint to look at the periods between noon and 8:00 A.M. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind, a summary table has been prepared using the period between noon and 8:00 A.M. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 6:00-6:30 P.M. period (when the machine is checked) if no errors are found, the time is given to the "running column." Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that any interruption of machine time that was not planned for is considered a failure in this table. In rare cases where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This overall system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" at any instant of time and the probability of a failure during any given interval of running time.

VI. COMMENTS ON THE ILLIAC AND RELATED FACILITIES.

Table III presents a summary of errors or interruptions for December.

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
12/1/55	19:19	:41	3	(1) Reader "J" tore tape. (2) Reader "I" tore tape. (3) Reader "G" tore tape.	:00	1:38	0
12/2/55	19:19	:41	3	(1) Stopped on 50 (2) Punch jammed. (3) Stopped on L4 order.	:00	1:58	0
12/5/55	19:50	:10	1	(1) DC went off. Ckt. No. 23 blew fuse.	:00	1:33	0
12/6/55	19:51	:09	3	(1) Stopped on S4, then started again. (2) Stopped on an L4 order, turned flipflop, started again. (3) Memory control chassis would not turn over.	:00	1:25	0
12/7/55	18:50	1:10	3	(1) Stopped on an S5 order. (2) Stopped several times on L4 order. (3) Stopped on S5 and L4 orders.	:00	1:00	0
12/8/55	20:00	:00	0		:00	1:19	0
12/9/55	20:00	:00	0		:00	2:36	0
12/12/55	19:37	:20	2	(1) Failed to read in three times, 4th try worked. (Leapfrog) (2) Tapes reading inconsistent by Reader "I" range bad.	:03	3:31	1
12/13/55	19:42	:18	3	(1) Tapes not reading correctly. (2) Punch failure (?) (3) Leapfrog 0 → 1 2^0.	:00	1:01	1
12/14/55	20:00	:00	0		:00	8:02	0
12/15/55	18:38	1:20	4	(1) Leapfrog. 0 → 1 2^{-8} (2) Reader "I" tore tape. (3) Reader "I" tore tape. (4) Reader "I" tore tape.	:02	7:46	1
12/16/55	19:58	:02	1	(1) Reader "I" tore tape.	:00	4:13	0
12/19/55	19:58	:02	0		:02	3:45	0
12/20/55	19:44	:14	0		:02	1:29	0

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
12/21/55	19:59	:01	1	(1) Scope hung up on 82. Turned DC off and on, went all right.	:00	1:28	0
12/22/55	20:00	:00	0		:00	1:27	0
12/23/55	20:00	:00	0		:00	1:25	0
12/27/55	17:17	:00	0		2:42*	1:29	
12/28/55	17:45	:00	0		2:15*	2:24	0
12/29/55	20:00	:00	0		:00	1:37	0
12/30/55	19:54	:00	0		:06	2:17	0
				* Computer off to hook wires to drum			
	409:42	5:06	24		5:12	53:23	3

TABLE III

Summary of Errors

Arithmetic Unit	0
Control	0
Reading Combined with Punching	0
Reading only	10
Punching only	2
Memory	2
Reader Control	0
Input Output Control	0
Fuse blew in Circuit #23, dc went off	1
Hung up on Scope Output Order	1
Total	24

The auxiliary drum memory unit has been installed in the room with Illiac and all electric connections have been completed to and from it so that testing of the drum memory can begin. Because not enough cable was on hand, only 72 of the total 200 tracks have been connected into the circuits. It is anticipated that the drum memory unit will be tested during the month of January.

VII. RESEARCH ON COMPUTER COMPONENTS. (This work is supported in part by the Office of Naval Research under Contract N6ori-07124.)

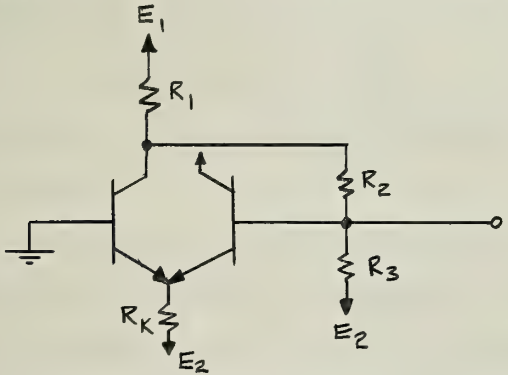
Transistor Test Computer

As mentioned in the May, 1955 report, a small computer has been designed and has been in the process of being built for the purpose of testing and becoming familiar with transistors in modest numbers. This computer contains 4 bit registers including shift registers of exactly the kind now contained in Illiac, except that transistor circuits with approximately 1 μs operation times are used. The test computer is to have a core memory of a total of 24 bits using transistor drive and read circuits. There will be a sufficient amount of control to enable the computer to add and subtract, multiply and divide under certain

simple and hence restricted conditions. It is not a general purpose computer in that even the small number of orders which can be handled are not interchangeable with numbers in the memory and no provision is made for storing numbers into the memory from certain parts of the arithmetic unit. This small computer is to serve as a testing ground for transistor elements. A more detailed report on it will be available later.

Computer Program for Transistor Flipflop Circuit

A program and code has been prepared to obtain numerical results for the constants used in the following simple transistor flipflop



The code is so constructed that the designer specifies the following quantities:

1. Power supply tolerance
2. Resistor tolerance
3. Negative supply voltage
4. Maximum total current taken from the bleeder to feed the external circuit and the emitter follower part of the flipflop
5. Maximum collector current rating
6. Least negative output voltage allowed
7. Least positive output voltage allowed
8. Maximum collector voltage rating
9. Minimum collector voltage allowed to avoid saturation
10. Maximum collector dissipation rating
11. Ratio of minimum to maximum α

The code proceeds to find the following quantities:

1. The positive supply voltage

2. The smallest allowable collector current
3. The three bleeder resistor values
   (R_k is not given by the code.)

The procedure used is as follows:

1. The positive supply is made as large as can be considered (100v).
2. The collector current is made equal to the maximum allowed current.
3. The collector current is reduced to as small a value as possible to still allow a solution for the three resistors (i.e. 3 positive real values).
4. The saturation condition is checked and the positive supply is reduced (re-computing the collector current and three resistors each time) until the saturation condition is just satisfied.
5. The maximum collector voltage condition is checked and the results are printed.

Many times the requirements cannot all be met. When this occurs the code prints the conditions which are not satisfied together with the values which came closest to working. This allows the designer to decide which required conditions might be changed to get a satisfactory solution.

Method of Multiplication

A method of multiplication, believed to be new, which for Illiac would require only 39 steps, was devised. The method requires a serial sensing of the multiplier digits, least significant digit first. A shift is executed for each zero of the multiplier, until the first one of the multiplier is sensed. The first one is noted, but otherwise ignored. Thereafter, when the multiplier digit sensed is a one, the multiplicand is added to the partial product and the sum is shifted; when the multiplier digit sensed is a zero, the multiplicand is subtracted from the partial product and the difference is shifted. The sign digit of the multiplier must be complemented before it is sensed. For example

$$1.\ 0\ 1\ 0\ 0\ 1\ 1\ 0\ 0 \quad \text{is treated as}$$

$$.\ (-1)(-1)(+1)(-1)(-1)(+1)\ 0\ 0\ .$$

The method is the inverse of non-restoring division.

VIII. CONSTRUCTION.

Again the major part of the shop work has been on the auxiliary drum memory. In addition to the drum memory work, a revised model of the photoelectric tape reader has been prepared in which many of the mechanical parts have been made stronger and more accessible for adjustment. This revised model has proved to operate well and to be quieter. If time permits it is anticipated that some alterations will be made on the other photoelectric tape readers to incorporate these better features.

IX. REPORTS AND SEMINARS.

Seminars

"A Floating Address Input Routine for the Illiac," Lily H. Seshu, December 6, 1955.

"The theory of Asynchronous Circuits," David E. Muller, December 13, 1955.

"Ferro-Electric Storage," Gene H. Leichner, December 20, 1955.

Reports

Internal Report No. 66, "Theory of Asynchronous Circuits," David E. Muller, December 6, 1955.

Internal Report No. 67, "Notes on the Use of Parallelism in Ultrahigh Speed Computer Designs," J. M. Wier, December 12, 1955.

"Two's Complement Multiplication in Binary Parallel Digital Computers," J. E. Robertson, IRE Transactions on Electronic Computers, EC-4:118, September, 1955.

X. PERSONNEL.

The personnel associated with the group and hence the contributors to this report are:

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